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Enhanced Multimedia Priority Services in LTE

Inter-working with CS networks to provide an end-to-end priority service

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Today commercial mobile networks are moving towards 4G networks which is based on Long Term Evolution (LTE) technology standard. LTE is based on Internet Protocol (IP) infrastructures and offers a wide range of broadband features. Currently in the 3G Cellular networks various priority services exist to handle the National Security threat created by natural and man-made events. As the networks evolve to the Next Generation Networks (NGN) one can expect that the same priority services (PS) are also supported in LTE networks.

During emergencies, the public networks can become overloaded due to a mass calling event or network failures. National Security (NS) and Emergency Preparedness (EP) personnel involved in emergency situation may have problems with network access. Enhanced Multimedia Priority Service (MPS) provides a mechanisms in the access and core networks to facilitate the needed priority communications.

This study addresses the NS/EP priority mechanisms in LTE that facilitates the high probability of call completion. These NS/EP priority mechanisms provide capabilities to NS/EP users for voice and data communications. The analysis is twofold. First, it studies the end to end call priority solution provided by telecom vendors on 3G network. Second it analyzes 3GPP standards NS/EP voice priority mechanisms for NGN networks. Finally it presents a potential solution to support the LTE priority mechanism on the Circuit Switch fallback (CSFB) to 1XRTT, limitations of the solution and further research areas with LTE access.

Keywords	LTE, NS/EP, NGN, 1XRTT, CSFB

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Abbreviations and Acronyms

1XRTT	1x (single-carrier) Radio Transmission Technology
1XCS IWS	1XRTT Circuit Switch Interworking
3GPP	Third Generation Partnership
3GPP2	Third Generation Partnership Project 2
ACM	Address Complete Message
ANM	Answer Message
ANSI	American National Standards Institute
BS	Base Station
BSC	Base Station Controller
BTS	Base Transceiver System
CDMA	Code Division Multiple Access
CMRS	Commercial Mobile Radio Service
CPC	Calling Party Category
CPG	Call Progress Message
CSFB	Circuit Switched Fall Back
DN	Directory Number
eMLPP	Enhanced Multi Level Precedence and Pre emption Service
EPS	Evolved Packet System
EUTRAN	Evolved Universal Terrestrial Radio Access Network
FCC	Federal Communications Commission
FOC	Full Operational capability
GCSNA	Generic Circuit Services Notification Application
GETS	Government Emergency Telecommunications Service
HLR	Home Location Register
HPC	High Probability of Completion
H-PURDA	Hard Public Use Reservation by Departure Allocation
HRPD	High Rate Packet Data
HSS	Home Subscriber Server
IEC	Interexchange carrier
IAM	Initial Address Message
IMS	IP Multimedia Subsystem
IOC	Initial Operational capability
IP	Internet Protocol

IR	Industry Requirements
ISUP	ISDN User Part
KAT	Keep Alive Timer
LEC	Local Exchange carrier
LTE	Long Term Evolution
MME	Mobility Management Entity
MS	Mobile Station
MSC	Mobile Switching Centre
MPS	Multimedia Priority Service
MTP	Message Transfer Part
MTPAS	Mobile Telecommunication Privileged Access Scheme
NCS	National Communications System
NGN	Next Generation Networks
NS/EP	National Security and Emergency Preparedness
OEC	Office of Emergency communication
PSTN	Public Switch Telephone Networks
QT	Queue Timer
RAT	Radio Access Technology
RRC	Radio Resource Control
SIP	Session Initiation Protocol
SRT	Status Response Timer
SRVCC	Single Radio Voice Call Continuity
SS7	Signalling System 7
TETRA	TErrerstrial Trunked Radio
TLDN	Temporary Local Directory Number
TQT	Trunk Queuing Timer
VLR	Visiting Location Register
VOIP	Voice over IP
WPS	Wireless Priority Services

1 Introduction

Today wireless communication has become indispensable in all aspects of life and the expectations is to have a ubiquitous network. In critical situations such as natural and manmade disaster even these networks can get destroyed, damaged or overloaded. Priority Services can ensure that key leadership personnel responsible for decision making and continuity planning processes can communicate even at times of network stress.

There are various international practices providing a traffic priority for public safety e.g. Mobile Telecommunication Privileged Access Scheme **(**MTPAS) in UK, Wireless Priority Services (WPS) and Government Emergency Telecommunications Service (GETS) in North America, dedicated TETRA networks in Europe, Middle East, Africa, Asia Pacific, Caribbean and Latin American. All these practices focused on voice, as it was the main service for earlier generation networks. The 3rd Generation Partnership Project (3GPP) telecommunications standard development organization has published a set of specifications for such priority services based on the requirements from governments. Their aim is to protect the country from different security threats. Telecom operators who have chosen to offer this service are mandated to provide compliance to these requirements.

1.1 Priority Services

In the United States of America there are two major emergency communication services which have served key roles in disaster response and recovery. They are GETS and WPS. GETS provides priority treatment of NS/EP calls within the landline segments of the PSTN. This service is managed by the Office of Emergency communication (OEC) (DHS office). The objective of OEC is to contract with commercial telephony carriers to provide these priority services on their public networks to OEC-authorized individuals. A GETS user is given a unique personal identification number and calling privileges. The user can invoke a GETS call using their own handset or dialing a specific access number (710-NCS) and entering a PIN which is validated by inter-exchange carriers.(Nolan, David, Stan, John R, Arye, 2013)

However, GETS does not address the wireless segments of the PSTN. Aftermath of the terrorist attacks on New York City and Washington DC on 11 September 2001, the damaged circuit switched telephone networks were unable to carry the suddenly enormous load of telephone calls. Accordingly, the Office of Emergency Communications (OEC) and former elements of the National Communications System (NCS), an arm of the U.S. Federal Government, established a Wireless Priority Service (WPS) in 2002. (Nolan, David, Stan, John R, Arye, 2013).

WPS provides high probability of call completion for priority users. WPS users are authorized by OEC and special privileges are given by carriers. WPS and GETS calls are invoked on a per call basis using certain dialing procedures. They do not preempt established calls in progress but provides priority access to radio traffic channels and trunk resources for Service Users making call requests. WPS also provides priority as the call progress through networks involved with call setup.

Figure *1* illustrates the overall network architecture for WPS and depicts various call paths NS/EP call may traverse.

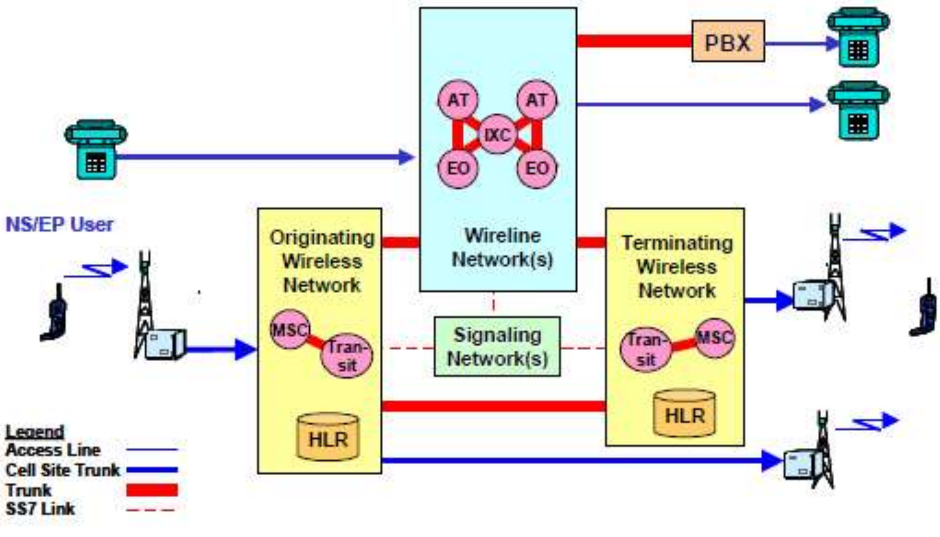

Figure 1. End to End Call completion –overall Architecture reprinted from WPS FOC 2004 : 3-7.

As can be seen in Figure 1, a call to a wireless user is first routed to its home network to determine the location of the user. This home wireless network (not explicitly shown in

Figure *1*) may be distinct from either the originating or terminating wireless network. The call path from an originating MSC to a Home MSC (HMSC), as well as from a HMSC to a terminating MSC, may traverse an intermediate IXC and/or LEC network.

Figure 2 illustrates points of congestion in wireline and wireless network.

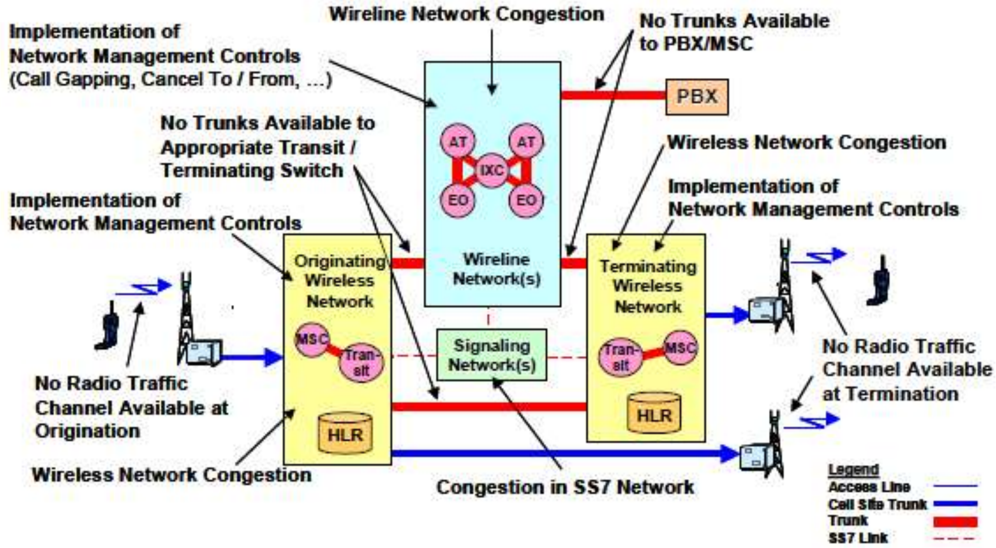

Figure 2. Major Blocking or Congestion points for WPS Reprinted from WPS FOC 2004:3-8.

While the major blocking or congestion points shown in Figure *2* are not the only congestion points within the various call paths, they are the most likely and will significantly impact the call flow before other blocking points are expected to begin to have an impact. WPS FOC address methods to overcome these congestion situation and provide high probability of call completion.

1.2 Next Generation Networks

3GPP roadmap to Next Generation of Networks is Long Term Evolution (LTE). LTE is based on Internet Protocol (IP) infrastructure. 3GPP proposal to achieve all IP infrastructure was LTE for Access and IP Multimedia Service Architecture (IMS) for Voice. IMS provides a better solution for voice with an all packet network infrastructure. However, moving to IMS introduced some challenges. First the voice services provided by circuit switch networks were of high quality, vendors and operators were unsure if the same quality of service can be achieved in packet networks. Second the operators had invested heavily in 3G infrastructure and shifting to a completely new architecture will hurt their CAPEX (Capital expense) and OPEX (operational expense). Faced with these challenges 3GPP proposed a phased delivery of IMS and an interim solution which is called a Circuit Switched Fallback (CSFB).

Circuit Switched Fallback is the technology which moves subscribers from LTE to 3G/2G networks to obtain a circuit switched voice. CSFB can exist only in areas where LTE is overlapped with other technology such as GSM and CDMA2000 1XRTT. The initial release of LTE defined the basic features of CSFB and further enhancements to it was defined in later releases. CSFB has various solutions as illustrated in Table 1 below.

Table 1. CS fallback options to 1xRTT (Rhode & Schwarz Voice and SMS in LTE, 2011:11).

Target RAT	Solutions	Release	UE Capability
CS Fallback to 1XRTT	RRC Connection Release with Redirection	Rel 8	Mandatory for UE supporting CSFB
	Enhanced 1xCSFB	Rel 9	e-CSFB- 1xRTT
	Enhanced 1xCSFB with concurrent HRPD Handover	Rel 9	e-CSFB-ConcPS-Mob1xRTT,Supportof HRPD, SupportedBandlistHRPD
	Dual receiver 1xCSFB(RRC Connection release without redirection)	Rel 9	rxConfig1xRTT(settoDual)
All CSFallback to 1xRTTcapable UE shall indicate that it supports 1XRTT and supported bandlist in the UE capability			

As shown in Table 1 there are four possibilities for CSFB to 1xRTT. The first option is the RRC connection release with redirection mechanism. This is the only solution available in 3GPP release 8 and mandatory for UEs supporting CSFB to 1xRTT. 3GPP release 9 added further options to support CSFB to 1xRTT. They are enhanced 1xCSFB, enhanced 1xCSFB with concurrent packet switched handover to High Rate Packet Data (HRPD), dual receiver 1xCSFB. *(Rhode & Schwarz Voice and SMS in LTE, 2011:11).*

Figure 3 depicts the reference architecture for CSFB to 1xRTT.

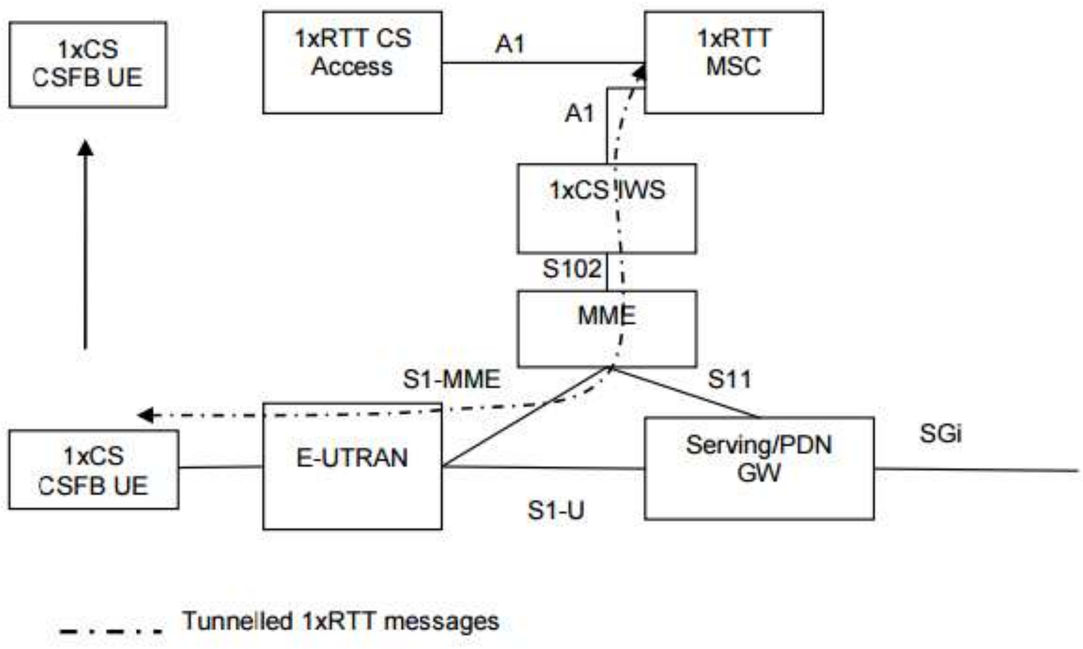

Figure 3. Reference architecture for CS fallback to 1xRTT CS (TR 23.272 2015: 70).

As shown in *Figure 3,* in 1XRTT CSFB architecture S102 reference point is shown between the MME and the 1xCS IWS (circuit switched fallback interworking solution function for 3GPP2 1xCS). The S102 reference point provides a tunnel between the MME and the 1xCS IWS to relay the 1xCS signalling messages (Rohde & Schwarz Voice and SMS in LTE, 2011). 1x CS signalling messages are those messages that are defined for A21 interface as described in 3GPP2 A.S0008-C and 3GPP2 A.S0009.

LTE networks have their advantages such as high data rate, low latency and packet optimized radio access technology to support flexible bandwidth deployments. Due to this, the number of customers using LTE is intensively growing and Mobile Network Service providers are facing congestion situations. During any disaster it is highly likely that

these networks will be congested. Hence, there is a need to address priority service requirements for NS/EP users involved in any disaster management activities. The OEC initiated a set of activities to define priority capabilities for voice communications in the packet-network environment similar to priority capabilities available in the circuit-switched networks (Nolan, David, Stan, John R, Arye, 2013). Enhanced Multimedia Priority Service (MPS) is the 3GPP roadmap to address these capabilities.
Figure 4 explains congestion in LTE Architecture.

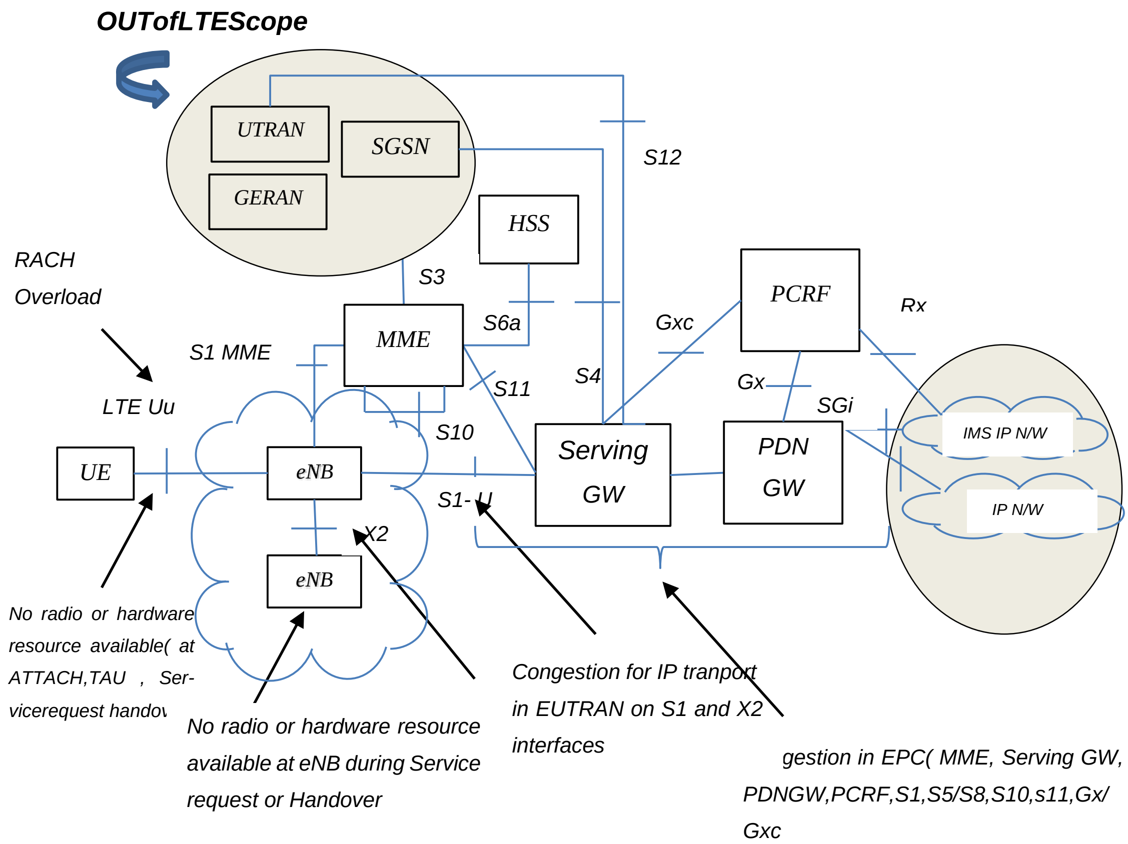

Figure 4. Possible Congestion points for EPS (EUTRA and EPC) (Carol-Lyn Taylor, David Nolan, Stan Wainberg 2013)

While the major blocking or congestion points shown in Figure 4 are not the only congestion points with the various call paths, they are the most likely and will significantly impact the call flow before other blocking points are expected to begin to have impact.

As per 3GPP specification TR 23.854 2011: 9:

”Multimedia Priority Service enables National Security/Emergency Preparedness (NS/EP) users to make priority calls/sessions using the public networks. These enhancements enable the network to support end-to-end priority treatment for MPS call/session origination/termination, including the Non Access Stratum (NAS) and Access Stratum (AS) signaling establishment procedures at originating/terminating network side as well as resource allocation in the core and radio networks for bearers. Priority treatment will be applicable to IMS based multimedia services, priority EPS bearer services and CS Fallback”.

To meet market needs equipment vendors designed CSFB with initial LTE releases. In these releases priority requirements were not fully considered to meet priority services. There were no support to propagate priority details within E-UTRAN Nodes. Later version of release added the support of these messages.

1.3 Research Question, Scope and Structure of Study

The objective of this study is to provide an end to end priority handling for CSFB Calls. Since CSFB has an LTE access connected to a 3G network, in order to provide end to end priority calls all nodes involved need to be studied and see how priority can be provided. The analysis is done in two folds. The first is to analyse Circuit Switched Fall Back calls priority handling requirements defined in Multimedia Priority Service standards and propose a solution on how nodes involved in these call flows can meet these requirements. The research focus is on the enhanced Circuit Switch Fallback (eCSFB) solution with no PS Handoff. CSFB supports different technologies and this thesis focuses on CSFB to 1XRTT Fallback.

The architectural requirements to achieve a priority handling for 1x CS Fallback MPS scenarios are the following as defined in 3GPP standards TR 23.854 2011: 9, 35-39:

“Mobile-terminated 1xCSFB call originated by service-user in 1xRTT

- If the MME receives a message from 1xCS IWS which includes a prioritized 1x CS Paging request, handling of the message should be in accordance with the priority level indicated in the request (i.e. independent of the fact that request originated in the 1xRTT network).

- If the MME receives a message from 1xCS IWS which includes a prioritized 1x CS Paging request, the MME and eNodeB shall be able to page the terminating UE in a prioritized way to establish the radio and S1 connection for subsequent CS Fallback procedures.

Mobile-originated 1xCSFB call by a service-user

- The MME and eNodeB shall be able to provide a prioritized treatment for a 1xCSFB request originated in E-UTRAN by a service-user."

The second is to analyse Wireless Priority Services requirements defined in WPS FOC and propose a solution for CSFB calls to meet these requirements when a call is moved to 3G. This thesis will study call flows defined in WPS FOC 2003 (see below), overload exemptions for WPS calls and finally define a CSFB WPS Call Flow. The research focus is to discuss technical issues to meet design goals on each node. The following call flows are analysed in detail

- Successful location update
- Successful WPS Call Origination – Radio Resources Available
- Successful WPS Call Termination– Radio Resources Available
- NS/EP call Progression – Successful call setup
- Successful WPS Call Origination – With Queuing for Radio Traffic Channel
- Successful NS/EP Call Termination – With Queuing for Radio Traffic Channel
- Trunk Queuing at Originating MSC and Terminating IXC - Successful Call Setup

To put it precisely, this study will answer the following research question:

. How to design End to End Priority Service feature for Enhanced CS Fallback Calls in CDMA System

Answering the question includes addressing the following sub-questions:

1. Clarify a high level design for MPS requirements for the CS fall back and changes on each node to meet those requirements
2. Clarify call flows for Enhanced CSFB WPS calls and design changes on each node to meet those requirements
3. Clarify limitations or design issues to meet Wireless Priority requirements for Enhanced CS Fall back calls

Section 2 describes the methods and the material used for this study. Section 3 describes Wireless Priority Services call flows on a 3G network and considers major call flows and solutions to achieve an end to end priority. Section 4 describes an overview of an enhanced CSFB solution and call flows as the proposal of this thesis is based on this solution. Section 5 describes a proposed solution for the research objective and Section 6 provides the conclusion.

2 Method and Material

This section discusses the research approach, research design and methods used in this study. It provides an overview about the data and data collection methods and analysis used.

2.1 Research Approach

To achieve the research goals and to contribute to solving the research problem, this study was conducted using a qualitative exploratory case study approach. This approach was selected as it is the most suitable for addressing the research question and the objective discussed in the Introduction.

According to Baxter P. and Jack S. (2008) the qualitative case study methodology should be considered when the focus of the study is to answer ‘how’ and ‘why’ questions and the study is aiming to cover contextual conditions. In this study the analysis of the Multimedia Priority Service interworking with CS Domain (CSFB) formed the case that needed to be studied. Then Baxter P. and Jack S. (2008) also instruct that after deciding to use a case study approach *the case of analysis need to be determined*. In this study it was North American CDMA market who has moved from 3G to LTE and adopted enhanced CSFB and implemented Wireless Priority Service.

After determining what the case is, it needs to be considered what will not be included in the case. In order to avoid the problem having too many objectives in the study Baxter P. and Jack S. (2008) suggested that *placing boundaries* on the case that can prevent the study from losing its focus. This would mean binding a case to time and place, time and activity, and by definition the case and its context. In this study, the case thus meant analysing the 3GPP Multimedia Priority Services (TR 23.854 2011: 9, 35-39) (time) to see how North American CDMA market (place and context) who has moved from 3G to LTE using enhanced CSFB can implement Wireless Priority Service for end to end calls. (Activity and context)

2.2 Research Design and Process

The research design of this study includes the following steps. First, the literature review was conducted for identifying theoretical knowledge about Multimedia Priority Service requirements in LTE. Second wireless priority services implemented in 3G was analysed. Third, the solution was suggested based on the above two.

Figure 5 depicts the research process with all the stages. These stages are detailed in the flowing sections.

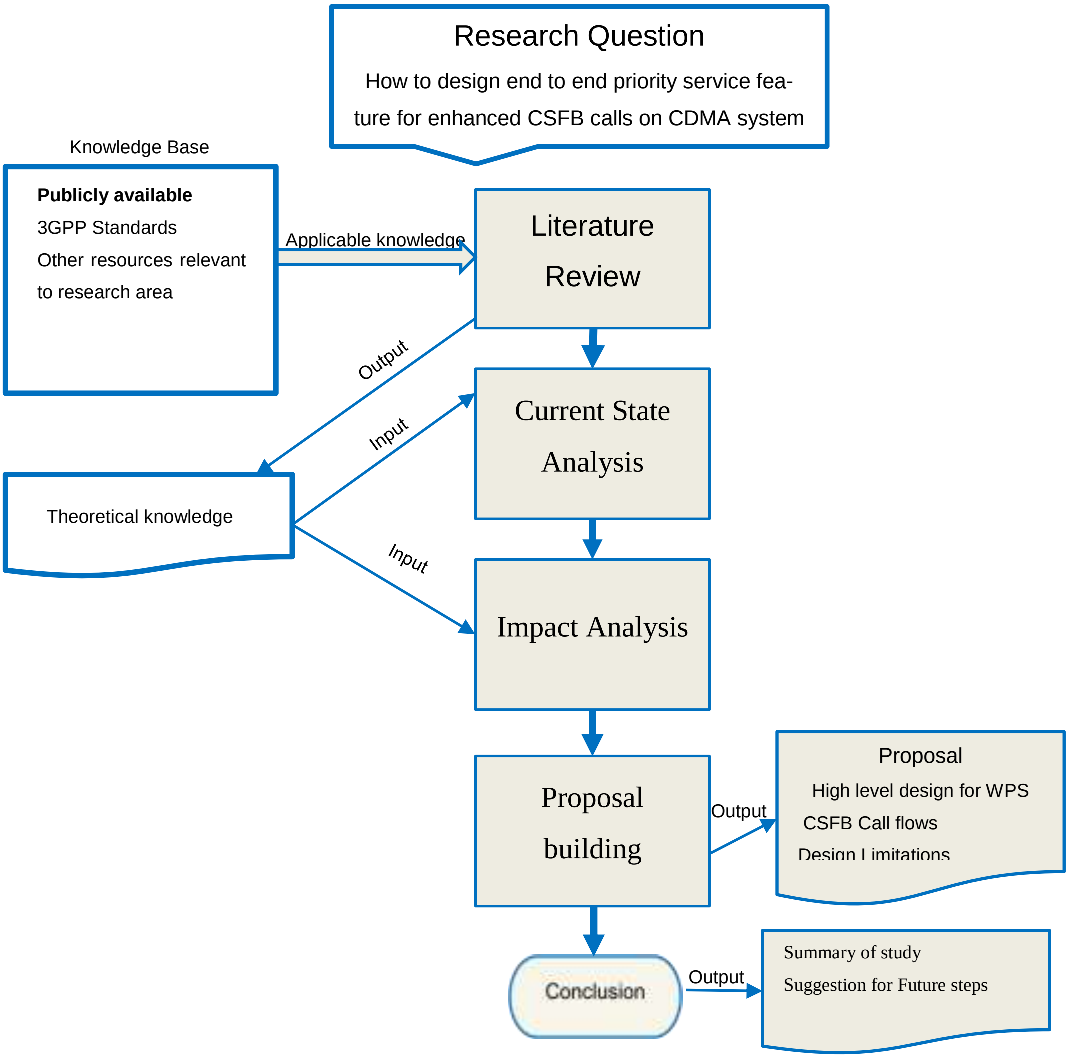

Figure 5. Research process of this study.

Literature review

The study started with a literature review on 3GPP Multimedia Priority Services (TR 23.854 2011: 9, 35-39) requirements to handle priority calls while interworking with CS Domain. Literature review was done by identifying, evaluating and interpreting the existing knowledge relevant to this study. It was based on the analysis of publically available scientific articles, books and other resources relevant to this study area.

To search for the existing knowledge and best practice, the relevant literature database sources were used, such as ACM digital library, IEEE Xplore® Digital Library, 3GPP and 3GPP2 specification, but not limiting the search within the above mentioned databases only. Various sources, articles, journals and white papers were found. Most of the sources were found by using key words including, for example, 'Multimedia Priority Service'. 3GPP Specification specifies requirements on each node based on which vendors can design their system.

Current State Analysis

The current state analysis was done by looking at design requirements of priority services features in CDMA 3G networks in North American market. As the operators move to LTE with enhanced CSFB as interim solution to support voice calls, till VoLTE is fully functional study focused on how CSFB voice calls can be the same when it enters 3G domain even when access has changed. The current state analysis was based on the data listed in the Table 2

Table 2. Details of data collection.

Type of Data	Content
3GPP Standard Documents	Wireless Priority Service Requirements and call flows Circuit Switch Fall Back call flows Multimedia Priority Service Interoperability Specification (IOS) for High Rate Packet Data (HRPD) Radio Access Network Interfaces with Session Control in the Access Network

Web Pages	Official website of Homeland Security
WPS Full operational capability	Wireless Priority Service Industry Requirements
Discussion	Latest requiremets in Standard with Product Owner researcher previous organization who has worked on CSFB.

As seen from the Table 2 above, the current state analysis focused on the analysis of Wireless Priority Services in the CDMA 3G networks and enhanced Circuit Switch fall back when 3G networks interworked with LTE. The analysis was based on the documentation, interviews and workshops. This included discussion in e-mails with people in the researcher previous organization who had worked on CDMA support for wireless priority services and CSFB.

Impact Analysis

Based on the input collected from literature review and current state analysis, impacts on CDMA system to meet LTE to CS Domain priority requirements were analysed. This took place by analysing how feasible the CDMA system was for the priority requirements. In practise this meant analysing the changes in CDMA system due to new call flows, parameters, existing call flows.

Proposal Building and Evaluation.

Fourth, based on the impact analysis, the study proposed changes in call flows to handle priority calls and areas of concern due to new call flows or information which is not available with change in access and way standards has defined them.

3 Wireless Priority Services

In 2004, Industry Requirements (IR) for a CDMA Wireless Priority Service (WPS) in support of NS/EP telecommunications services were completed and service acquisition was initiated. The IR adhered to the Federal Communications Commission (FCC) Report (FCC R&O, 1998). The initial deployment of WPS allows qualified and authorized NS/EP users to obtain priority access to radio traffic channels during situations when Commercial Mobile Radio Service (CMRS) network congestion is blocking call attempts. WPS interoperates with the Government Emergency Telecommunications Service (GETS) and provides an end-to-end service, e.g., mobile to mobile, mobile to wireline, and wireline to mobile. WPS facilitates emergency response and recovery operations in response to natural and man-made disasters and events such as floods, earthquakes, hurricanes, and terrorist attacks. WPS also supports both national and international emergency communications.

3.1 Wireless Network Reference Model

The high-level architecture for WPS is based on the current architecture for wireless Carrier networks. The wireless network reference model, as adopted by ANSI TIA standards, is discussed in (TSB-100, 2001). Figure 6 illustrates a portion of the overall wireless network reference model, including the architectural components that are relevant for providing WPS.

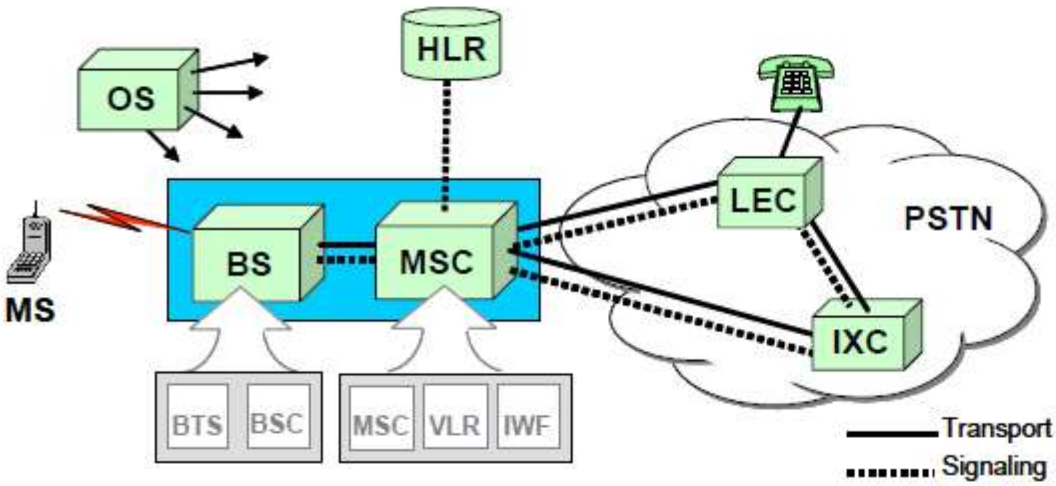

Figure 6. Wireless Network Reference Model reprinted from WPS FOC 2004:3-1.

As shown in Figure 6 each component is designed to provide certain functions in the network model and the description of components are as follows. The description is extracted from (TSB-100, 2001)

Base Station (BS)

A BS is an entity that provides the means for MSs to access network services using radio. A BS includes a Base Station Controller (BSC) and a Base Transceiver System (BTS).

Base Station Controller (BSC)

The BSC is an entity that provides control and management for one or more BTSs. The BSC exchanges messages with both the BTS and the MSC. Traffic and signaling concerned with call control, mobility management, and MS management may pass transparently through the BSC.

Base Transceiver System (BTS)

The BTS is an entity that provides transmission capabilities across the radio interface. The BTS consists of radio devices, antenna and equipment.

Home Location Register (HLR)

The HLR is the location register to which a user identity is assigned for record purposes such as subscriber information (e.g., Electronic Serial Number (ESN), Mobile Directory Number (MDN), Profile Information, Current Location, and Authorization Period).

Inter-Working Function (IWF)

The IWF provides a translation of the user traffic on a data call between the fixed network and the air interface.

Mobile Station (MS)

An MS is a wireless terminal used by a subscriber to access network services over a radio interface. The MS is the interface equipment used to terminate the radio path at the subscriber. MSs include portable units (e.g., hand-held units), units installed in vehicles, and somewhat paradoxically, fixed location MSs.

Mobile Switching Center (MSC)

The MSC switches circuit mode MS-originated or MS-terminated traffic. An MSC is usually connected to at least one BS. It may connect to the other public networks (PSTN, ISDN, etc.), other MSCs in the same network, or MSCs in different networks. The MSC may store information to support these capabilities. MSC may be packet MSC which supports IP and SIP.

Operations System (OS)

OSs are responsible for overall management of the wireless network. Their functions include the following:

- Performance management — evaluation and reporting of network behavior and effectiveness.
- Fault management — detection, isolation, and correction of abnormal operation.
- Configuration management — control, identification, and data administration of network entities.
- Accounting management — measurement of network usage and collection of accounting records.
- Security management — protection from unauthorized access.

Public Switched Telephone Network (PSTN)

The PSTN is defined in accordance with the appropriate ANSI T1 Standards.

Note: The MSC may connect to the PSTN via direct IXC facilities or via a LEC network (as depicted in Figure *6*). The MSC may alternately route such calls (to a LEC or an IXC network) via a wireless transit node. In addition, MSCs may connect directly with other MSCs.

Visitor Location Register (VLR)

The VLR is the location register other than the HLR used by an MSC to retrieve information for handling of calls to or from a visiting subscriber. The VLR may or may not be located within, and be indistinguishable from, an MSC. The VLR may serve more than one MSC.

In addition, a Service Provider may use transit nodes within its network. A Service Provider transit node is a switch within the Service Provider's network that is not the originating or terminating MSC. A wireless transit node may be a Home MSC[1] or a tandem MSC. One or more transit nodes may be used when an originating MSC does not contain a direct path to a terminating MSC to complete a call.

3.2 CDMA Wireless Priority Services Subscription

WPS is implemented as a subscription service for authorized NS/EP users only. There are five WPS National Security and Emergency Preparedness (NS/EP) criteria. 1 being the highest priority level and 5 being the lowest priority level. Service User request for WPS priority assignment and NCS approves the request. The priority levels, as defined in the FCC R&O, are shown in Table 3.

Table 3. Priorities for Service Users (WPS FOC, 2004:2-5).

Priority Level	**Responsibility**	**Qualifying Criteria**
1	Executive Leadership and Policy Makers	Users who qualify for the Executive Leadership and Policy Makers priority will be assigned Priority 1. A limited number of CMRS technicians who are essential to restoring the CMRS networks may also receive this highest priority treatment.
2	Disaster Response / Military Command and Control	Users who qualify for the Disaster Response/Military Command and Control priority will be assigned Priority 2. Individuals eligible for Priority 2 include personnel key to managing the initial response to an emergency at the local, State, regional and Federal levels. Personnel selected for this priority should be responsible for ensuring the viability or reconstruction of the basic infrastructure in an emergency area. In addition, personnel essential to the continuity of government

		and national security functions (e.g., conducting international affairs and intelligence activities) are included.
3	Public Health, Safety, and Law Enforcement Command	Users who qualify for the Public Health, Safety, and Law Enforcement Command priority will be assigned Priority 3. Eligible for this priority are individuals who direct operations critical to life, property, and maintenance of law and order immediately following an event.
4	Public Services/ Utilities and Public Welfare	Users who qualify for the Public Services/Utilities and Public Welfare priority will be assigned Priority 4. Eligible for this priority are those users whose responsibilities include managing public works and utility infrastructure damage assessment and restoration efforts and transportation to accomplish emergency response activities.
5	Disaster Recovery	Users who qualify for the Disaster Recovery priority will be assigned Priority 5. Eligible for this priority are those individuals responsible for managing a variety of recovery operations after the initial response has been accomplished.

The qualifying criteria shown in Table *3* are representative examples of the types of users within each priority level.

3.3 WPS Feature Objective

WPS provides the following capability to improve the likelihood of successful call completion.

- Downloading of subscription information from HLR to VLR
- Priority Call Origination: Identify its WPS call by analyzing digits dialed and validating with user subscription and pass this special marking to subsequent nodes along the call path to enable subsequent WPS processing
- Priority Call Termination: Identify its WPS call by decoding WPS parameters passed in the messages and provide priority treatment for incoming NS/EP call
- Priority Call Queuing: Enable the mobile origination and termination to be queued on the MSC in the event of lack of either radio or trunk bearer resources.

- Priority Call Progression and Queuing: Queue the trunk resources (between the originating MSC and the next node in the PSTN, or the originating MSC to the terminating MSC) in case of network congestion
- special routing to a High Probability of Completion (HPC[1])-capable inter-exchange carrier (IXC) when IXC service is required, and to have Signaling System #7 (SS7) signaling marked with an NS/EP call indication and with a Message Transfer Part (MTP) priority of “1”.
- WPS Enhanced Overload Performance: Dedicate class 11 to WPS and to provision it on mobiles subscribed to WPS. Exempt WPS calls from all overload conditions.

Above mentioned list are subset of WPS FOC requirements and the study has chosen above functional areas to be discussed in detail.

3.3.1 Downloading WPS Subscription Information

WPS priority details of user are stored as subscription information in Home Location Register. This information is downloaded to VLR during following events such as registration, addition of user subscription to HLR database, service user originating call immediately entering new zone without registration.

Figure *7* describes the sequence of messages exchanged between various nodes in 3G wireless network when MS moves into a new zone and successfully registers in the system. Details of message, parameters that are WPS specific are explained letter by letter (letters referring A to Z).

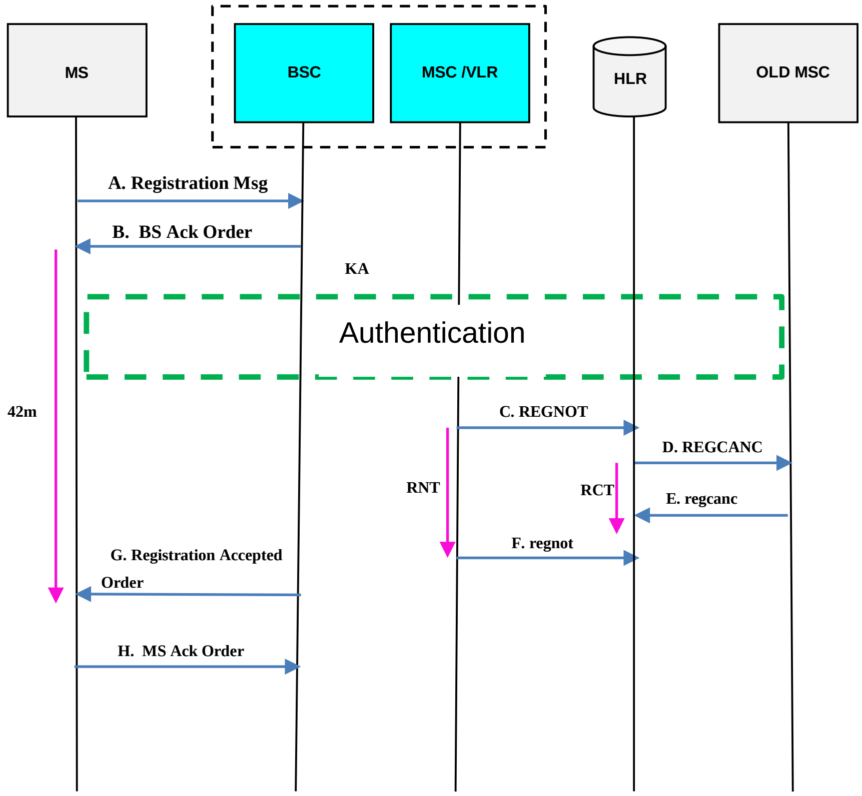

Figure 7. Successful Location Update. (WPS FOC, 2004:4-2)

A. When the MS detects that it has roamed into a new location area, it sends a Registration Message to the new serving system (BS/MSC).

B. The BS/MSC acknowledges the receipt of the Origination Message by sending a Base Station Acknowledgment Order to the MS. The MS starts timer T42m.

NOTE: The BS/MSC transmits a Base Station Acknowledgment Order to the MS to acknowledge the receipt of the Registration Message if no message directed to the MS (e.g., Registration Accepted Order) is available within ACC_TMO1 x 80 ms after the receipt of the Registration Message.

C. The MSC may invoke authentication procedures upon receipt of the Registration Message. The MSC sends a Registration Notification (REGNOT) message to the HLR (including the identity of the MS and the updated location information) and starts timer RNT, waiting for the associated response message.

D. The HLR sends a Registration Cancellation (REGCANC) message to the MSC where the MS had previously been registered. The HLR starts timer RCT, waiting for the associated response message.

E. Upon receipt of the REGCANC message, the old MSC removes all record of the MS from its memory and confirms the deletion of the subscriber information from its database by sending a Registration Cancellation (regcanc) RETURN RESULT message to the HLR.

F. The HLR stops timer RCT and updates its database with the new location of the MS, retrieves the subscriber's profile information, confirms that the MS is eligible for service in the new area, and sends a Registration Notification (regnot) RETURN RESULT message with the subscriber profile information to the new MSC. For Service Users, this message indicates that the user is subscribed to WPS and includes the Service User's priority level.

G. The MSC stops timer RNT and updates its database with the subscriber's profile. The BS/MSC sends a Registration Accepted Order to the MS.

H. The MS stops timer T42m and sends a Mobile Station Acknowledgment Order to the BS/MSC to acknowledge the receipt of the Base Station Acknowledgment Order.

As explained in Figure 7 the above sequence of events results in WPS priority details available on MSC which is later used to validate service user.

3.3.1.1 WPS Indicator

Figure 8 shows WPS Priority information defined as per ANSI/TIA standard (ANSI/TIA/EIA-41 D, 1997). WPS Indicator parameter indicates that the requesting MS is authorised to use WPS, and indicates priority assigned to

<table>
<tr><td colspan="3">Field</td><td colspan="3">Value</td><td colspan="2">Type</td><td colspan="2">Notes</td></tr>
<tr><td colspan="3">Identifier</td><td colspan="3">WPS Indicator
IMPLICIT OCTET STRNG</td><td colspan="2">M</td><td colspan="2">a</td></tr>
<tr><td colspan="3">Length</td><td colspan="3">variable octets</td><td colspan="2">M</td><td colspan="2"></td></tr>
<tr><td colspan="10">Contents</td></tr>
<tr><td>H</td><td>G</td><td>F</td><td>E</td><td>D</td><td>C</td><td>B</td><td>A</td><td>Octet</td><td>Notes</td></tr>
<tr><td colspan="3">Reserved</td><td>PCD</td><td colspan="4">WPS Priority Level</td><td>1</td><td>b,c,d</td></tr>
<tr><td colspan="8">…</td><td>n</td><td>e</td></tr>
</table>

Figure 8. WPS Indicator Parameter.

The notes shown in Figure 8 is explained as follows

a. The parameter identifier value ‘9F826D’ (Hex) has been assigned by the standards bodies for the WPSIndicator parameter.
b. Ignore reserved bits on receipt and set to zero on sending.
c. Only values “1” through “5” are allowed for the WPS Priority Level. A value of “1” indicates the highest priority for WPS and value “5” indicates the lowest priority for WPS.
d. The PCD field in the WPSIndicator parameter is not meaningful for the HLR-based solution for WPS. The HLR should set this field to value 0. The MSC should ignore the received value.
e. Ignore extra octets if received. Send only defined (or significant) octets.

Table. *4* shows WPS Priority Level values for WPSIndicator Parameter.

Table. 4 WPS Priority Level Values for WPSIndicator Parameter.

WPS Priority Level (Octet 1, bits A-D)										
Bits	H	G	F	E	D	C	B	A	Value	Meaning
					0	0	0	0	0	Not Used
					0	0	0	1	1	WPS Priority Level 1
					0	0	1	0	2	WPS Priority Level 2
					0	0	1	1	3	WPS Priority Level 3
					0	1	0	0	4	WPS Priority Level 4
					0	1	0	1	5	WPS Priority Level 5
					0	1	1	0	6	Reserved. If received treat
									through	
					1	1	1	1	15	as non service user

As defined in Table. 4 octet 1 bits A-D are used for WPS priority level. 4 bits can represent 16 values out of which only 5 values are defined and remaining are reserved. Based on this definition HLR and VLR components perform the encoding and decoding.

3.3.2 WPS Call Processing Call Flows

This section illustrates WPS call flows describing how calls are processed at various nodes of CDMA system and what are special messages and parameters used to identify its WPS call and propagate the same so subsequent nodes can provide priority treatment. This section discusses only the success scenarios.

3.3.2.1 Priority Call Origination

When NS/EP user originates WPS call by invoking feature code (*272) + DN, MSC determines call is a WPS call by digit analysis and user subscription. MSC requests BSC to allocate radio resources for the call. On Successful allocation of radio resources MSC proceeds with setting up priority call and pass this 'WPS call' special marking to subsequent nodes for WPS processing

Figure 9 illustrates successful WPS invocation by an authorized Service User.

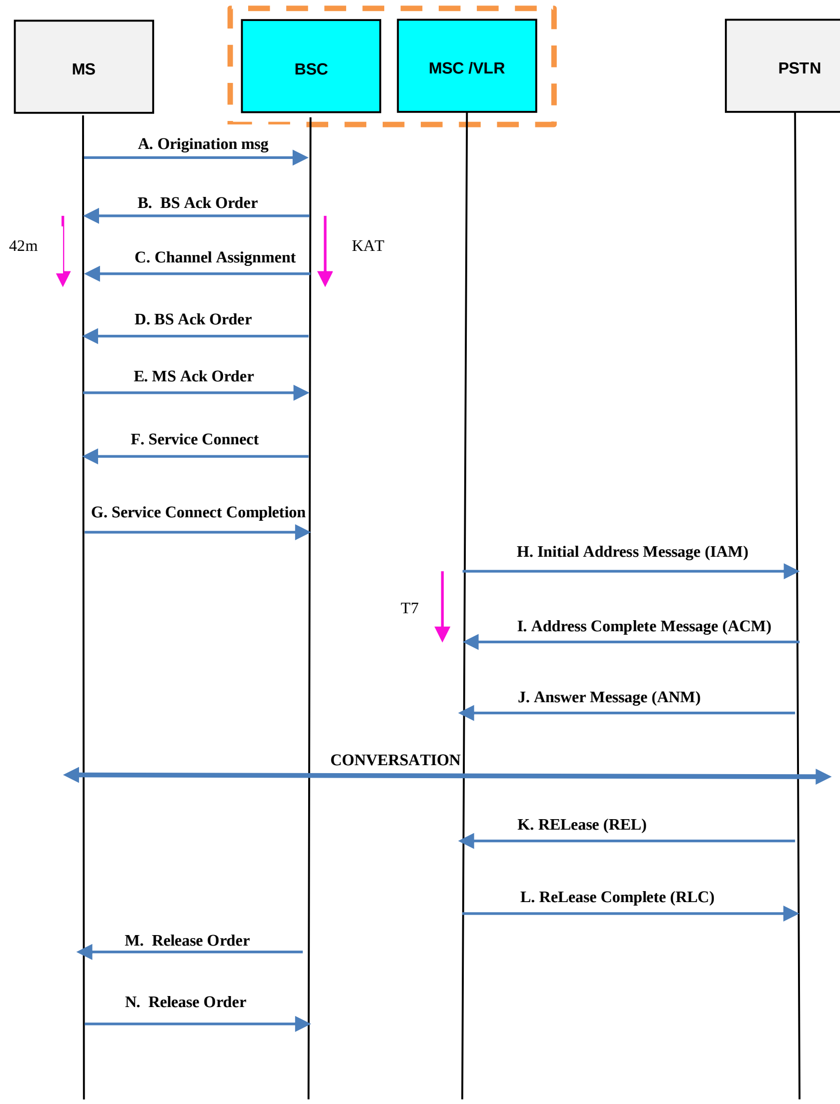

Figure 9. Successful WPS Call Origination – Radio Resources Available. (WPS FOC, 2004:4-4)

In Figure *9*, the assumption is that radio traffic channels are available when the WPS call is attempted. The sequence of events depicted in call flow is explained in detail letter by letter. The details are from (WPS FOC 2004:4-4*)*

A. The caller dials *272 + DN. The MS sends an Origination Message to the BS/MSC (via the Access Channel).

NOTE: The Origination Message may indicate that it is to be followed by an Origination Continuation Message. In this particular scenario, the full set of dialed digits are assumed to be contained in the Origination Message, so the Origination Continuation Message is not used.

B. The BS/MSC acknowledges the receipt of the Origination Message by sending a Base Station Acknowledgment Order to the MS. The MS starts timer T42m. The BS/MSC starts a Keep-Alive Timer (KAT).

NOTE: The BS/MSC transmits a Base Station Acknowledgment Order to the MS to acknowledge the receipt of the Origination Message if no message directed to the MS (e.g., Channel Assignment Message, Feature Notification Message) is available within ACC_TMO2 x 80 ms

after the receipt of the Origination Message.

NOTE: Timer KAT is a new timer required at the BS/MSC to avoid the expiration of timer T42m at the MS. It is set to a value smaller than T42m to account for delays that could occur and to ensure that a Status Request Message is sent before timer T42m expires at the MS. T42m is set

to 12 seconds.

C. The BS/MSC determines (based on the *272 prefix as the leading dialed digits within the Origination Message) that this is a WPS invocation. The MSC verifies that the caller is subscribed to WPS, based on the profile information previously obtained from the HLR (as described in step G of Section 3.3.1), and uses this profile information to determine the priority associated with that Service User. The BS/MSC determines that a radio traffic channel is available, and therefore attempts to assign a radio traffic channel at this time. The BS/MSC begins sending null Traffic Channel data over that channel and sends a Channel Assignment Message to the MS. The BS/MSC cancels timer KAT. The MS cancels timer T42m.

NOTE: The Channel Assignment Message, as used throughout this section, can be replaced with an Extended Channel Assignment Message.

D. The MS receives a sequence of valid frames and begins sending the Traffic Channel preamble.The BS/MSC detects this and sends a Base Station Acknowledgment Order to the MS on the Forward Traffic Channel.

E. The MS acknowledges the receipt of the Base Station Acknowledgment Order by transmitting the Mobile Station Acknowledgment Order and by sending null Traffic Channel data over the Reverse Traffic Channel.

F. The BS/MSC sends the Service Connect Message / Service Option Response Order to the MS specifying the service configuration for the call. The MS begins processing traffic in accordance with the specified service configuration.

G. On receipt of the Service Connect Message, the MS responds with a Service Connect Completion Message. The BS/MSC uses the dialed digits, excluding the *272 prefix, to determine the intended destination for the call. The BS/MSC sends an ISUP Initial Address Message (IAM) to the PSTN and starts ISUP timer T7. The ISUP IAM message includes the Calling Party's Category (CPC) Parameter set to "NS/EP Call" and (if configured) the Precedence parameter set based on the priority level (as determined based on the Service User's profile). The IAM may contain additional routing information to direct the call to HPC-capable networks. The call processing flow proceeds normally beyond this point.

I. The PSTN sends an ISUP Address Complete Message (ACM) to the MSC. The MSC cancels ISUP timer T7.

J. When the terminating party answers, the PSTN sends an ISUP ANswer Message (ANM) to the MSC. The call is established and conversation continues.

K. When the terminating party releases, the PSTN sends an ISUP RELease message (REL) to the MSC.

L. The MSC responds to the PSTN with an ISUP ReLease Complete (RLC) message.

M. The BS/MSC sends an OrderMessage on the Forward Traffic Channel to the MS, with the Order Code (ORDER) and Order Qualification Code (ORDQ) fields set to indicate "Release Order (no reason given)".

N. The MS sends an Order Message on the Reverse Traffic Channel to the BS/MSC, with the ORDER / ORDQ fields set to indicate "Release Order (normal release)".

As explained above sequence of events enables WPS call to be setup successfully on MSC and WPS marking propagated to other nodes so that high probability of call completion can be given.

3.3.2.2 Priority Call Termination

When Terminating MSC receives a call with NS/EP parameters it determines the call is NS/EP and call priority needs to be provided. It pages the mobile based on information available in the VLR and upon receiving page response requests BSC to allocate radio resources. Terminating user need not be authorized personnel to receive priority treatment as WPS call is based on Originator.

Figure 10 illustrates successful NS/EP call termination.

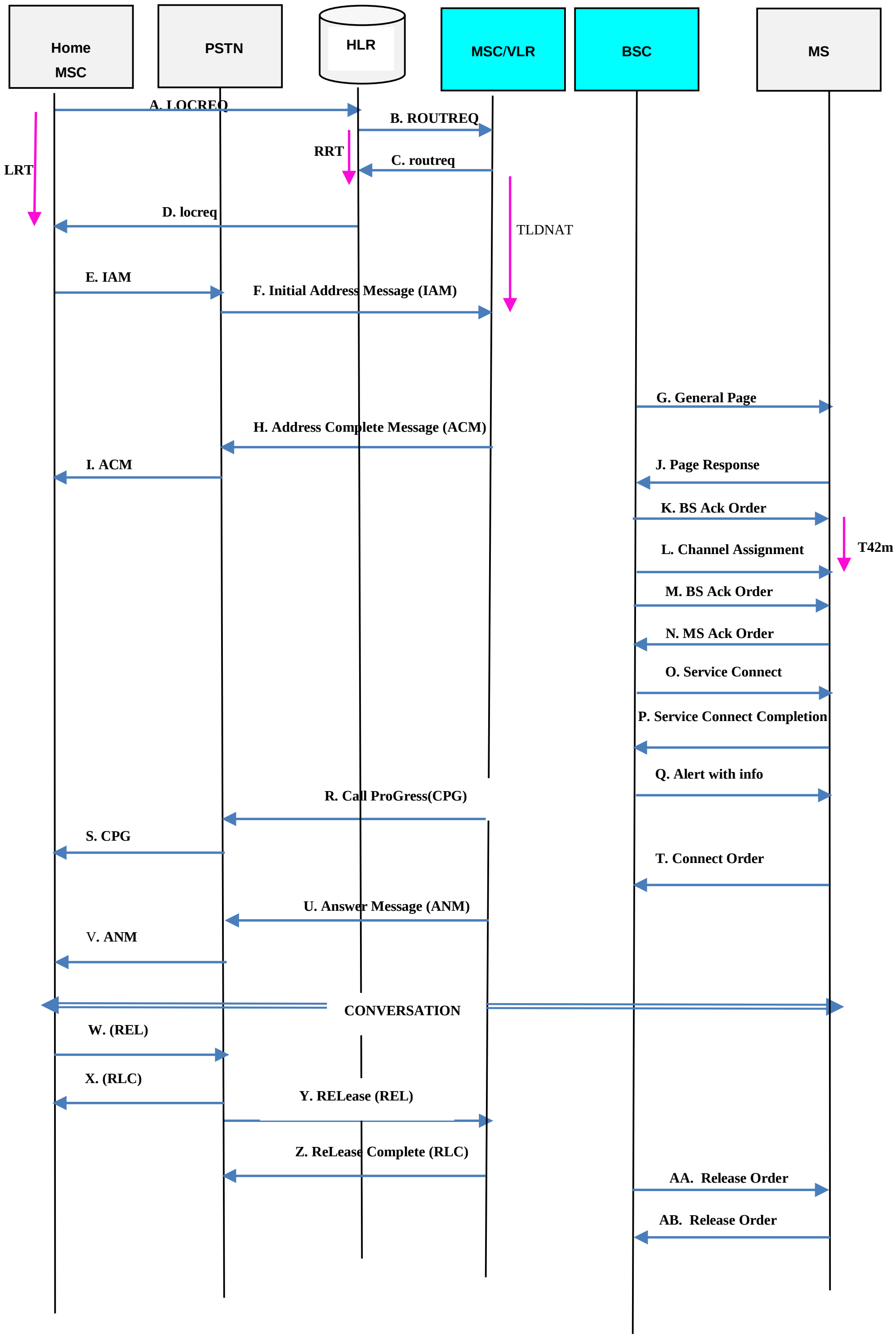

Figure 10. Successful NS/EP Call Termination – Radio Resources Available. (WPS FOC, 2004:4-31)

In Figure *10*, the assumption is that radio traffic channels are available when the incoming NS/EP call is received by the terminating BS/MSC. The sequence of events depicted in call flow is explained in detail letter by letter. The details are from (WPS FOC 2004:4-31*).*

A-D. For this scenario, an NS/EP call is placed to a terminating MS. The terminating MS is roaming and the call is delivered to the terminating MSC via appropriate interactions between the called party's Home MSC, the called party's HLR, and the terminating MSC that is now serving the called party. This processing is depicted in steps A through D of Figure *10*.

A. When call has to be terminated first step is to identify where mobile is. Hence Home MSC or GW MSC will send LOCREQ to HLR. WPSCallIndicator parameter is included to indicate to HLR its WPS call. LRT timer is started.

B. HLR upon receiving LOCREQ determines mobile is roaming and sends ROUTREQ to Serving MSC. HLR forwards WPSCallIndicator parameter. HLR starts RRT timer

C. Serving MSC allocates TLDN and starts TLDN timer. Since its NS/EP call TLDN timer value is increased to handle delay in IAM coming in later phase from originating MSC. Serving MSC sends *routreq* back to HLR.

D. HLR cancels RRT timer and forwards TLDN to Home MSC or GW MSC building *locreq*.

E. When the Home MSC receives the *locreq* response from the called party's HLR, it determines the appropriate routing for the call, based on the TLDN assigned in step C. In this case, it routes the call via the PSTN. The Home MSC sends an ISUP IAM message, containing the TLDN as the called party number. The ISUP IAM message includes the CPC parameter set to "NS/EP Call" and includes the Precedence parameter (if available and configured).

F. On receipt of the ISUP IAM message, the PSTN sends a corresponding ISUP IAM message to the terminating MSC.

G. On receipt of the ISUP IAM message, the BS/MSC cancels timer TLDNAT, determines the corresponding MSID associated with that TLDN, and sends a General Page Message to the MS.

H. The terminating MSC sends an ISUP ACM message to the PSTN. The ISUP ACM message includes the Called Party's Status Indicator field in the Backward Call Indicators parameter set to "no indication".

I. The PSTN sends an ISUP ACM message to the Home MSC.

J. The MS responds to the General Page Message by sending a Page Response Message to the BS/MSC.

K. On receipt of the Page Response Message from the MS, the BS/MSC sends a Base Station Acknowledgment Order to the MS. The MS starts timer T42m.

L. The BS/MSC determines that a radio traffic channel is available, and therefore attempts to assign a radio traffic channel at this time. The BS/MSC begins sending null Traffic Channel data over that channel and sends a Channel Assignment message to the MS. The MS cancels timer T42m.

M. The MS receives a sequence of valid frames and begins sending the Traffic Channel preamble. The BS/MSC detects this and sends a Base Station Acknowledgment Order to the MS.

N. The MS acknowledges the receipt of the Base Station Acknowledgment Order by transmitting the Mobile Station Acknowledgment Order.

O. The BS/MSC sends the Service Connect Message / Service Option Response Order to the MS specifying the service configuration for the call. The MS begins processing traffic in accordance with the specified service configuration.

P. On receipt of the Service Connect Message, the MS responds with a Service Connect Completion Message.

Q. The BS/MSC sends an Alert with Information Message to the MS on the Forward Traffic Channel. The MS alerts the called party.

R-S. Optionally, the terminating MSC sends an ISUP CPG message to the PSTN and the PSTN sends an ISUP CPG message to the Home MSC.

T. When the user responds to the alerting indication (i.e., answers), the alerting is cancelled and the MS sends a Connect Order Message on the Reverse Traffic Channel to the BS/MSC.

U. When the terminating BS/MSC receives the Connect Order Message, it sends an ISUP ANM message to the PSTN.

V. The PSTN sends an ISUP ANM message to the Home MSC. The call is established and conversation continues.

W. When the originating party releases, a release indication is sent to the Home MSC and the Home MSC sends an ISUP REL message to the PSTN.

X. The PSTN responds to the Home MSC with an ISUP RLC message.

Y. The PSTN sends an ISUP REL message to the terminating BS/MSC.

Z. The terminating BS/MSC responds to the PSTN with an ISUP RLC message.

AA. The BS/MSC sends an Order Message on the Forward Traffic Channel to the MS. The ORDER / ORDQ fields are set to indicate “Release Order (no reason given)”.

AB. The MS sends an Order Message on the Reverse Traffic Channel to the BS/MSC. The ORDER / ORDQ fields are set to indicate “Release Order (normal release)”

As explained, above sequence of events enables WPS call to be setup successfully on terminating MSC.

3.3.2.2.1 WPS Call Indicator

WPS Call Priority information is defined in (ANSI/TIA/EIA-41 D, 1997) standard as shown in Figure. *11*. WPSCallIndicator parameter indicates an incoming NS/EP call.

<table>
<tr><td colspan="4">Field</td><td>Value</td><td colspan="2">Type</td><td colspan="3">Notes</td></tr>
<tr><td colspan="4">Identifier</td><td>WPSCallIndicator IMPLICIT OCTET STRNG</td><td colspan="2">M</td><td colspan="3">a</td></tr>
<tr><td colspan="4">Length</td><td>variable octets</td><td colspan="2">M</td><td colspan="3"></td></tr>
<tr><td colspan="10">Contents</td></tr>
<tr><td>H</td><td>G</td><td>F</td><td>E</td><td>D</td><td>C</td><td>B</td><td>A</td><td>Octet</td><td>Notes</td></tr>
<tr><td colspan="4">Re-served</td><td>WPS Priority Level</td><td></td><td></td><td></td><td>1</td><td>b,c,d</td></tr>
<tr><td>…</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>n</td><td>e</td></tr>
</table>

Figure. 11 WPS Call Indicator

The notes shown in Figure. *11* is explained as follows

Notes:

a. The parameter identifier value ‘9F823E’ (Hex) has been assigned by the standards bodies for the WPSCallIndicator parameter.
b. Ignore reserved bits on receipt and set to zero on sending.
c. Ignore extra octets if received. Send only defined (or significant) octets

Table 5. WPS Priority Level Values for WPSCallIndicator Parameter.

WPS Priority Level (Octet 1, bits A-D)										
Bits	H	G	F	E	D	C	B	A	Value	Meaning
					0	0	0	0	0	Not Used
					0	0	0	1	1	WPS Priority Level 1
					0	0	1	0	2	WPS Priority Level 2
					0	0	1	1	3	WPS Priority Level 3
					0	1	0	0	4	WPS Priority Level 4
					0	1	0	1	5	WPS Priority Level 5
					0	1	1	0	6	Reserved. If received treat
									through	
					1	1	1	1	15	as non WPS call

As defined in Table *5* octet 1 bits A-D are used for WPS call priority level. 4 bits can represent 16 values out of which only 5 values are defined and remaining are reserved. Based on this definition HLR and MSC components perform the encoding and decoding.

3.3.2.3 Priority Call Progression

WPS calls are given priority treatment end to end by using High probability of Call completion methods (GR-2931-CORE, 1996). As the call progresses through interconnected networks call priority is propagated which enables other networks to provide priority treatment if system is enabled. HPC capabilities rely on the deployment of SS7 switching system capabilities, including the ability to:

- Provide a Message Transfer Part (MTP) message priority of “1” for the SS7 ISUP Initial Address Message (IAM) to increase the probability of delivery of the SS7 message to the next exchange in case of congestion in the signaling network.
- Set the Calling Party’s Category (CPC) parameter within the IAM to identify the call as an NS/EP call based on the dialed digits (e.g., based on a GETS DN).
- Pass the CPC parameter through the telecommunications network.
- Recognize the NS/EP call indication in the CPC parameter in the IAM of an incoming call in order to afford special HPC treatment.
- Set the (optional) Precedence parameter within the ISUP *IAM* message to indicate the specific priority of a WPS call as assigned in the originating Service Provider’s network.

Figure 12 shows a successful NS/EP call progression call flow involving 1XC and LEC and then terminated to a MSC.

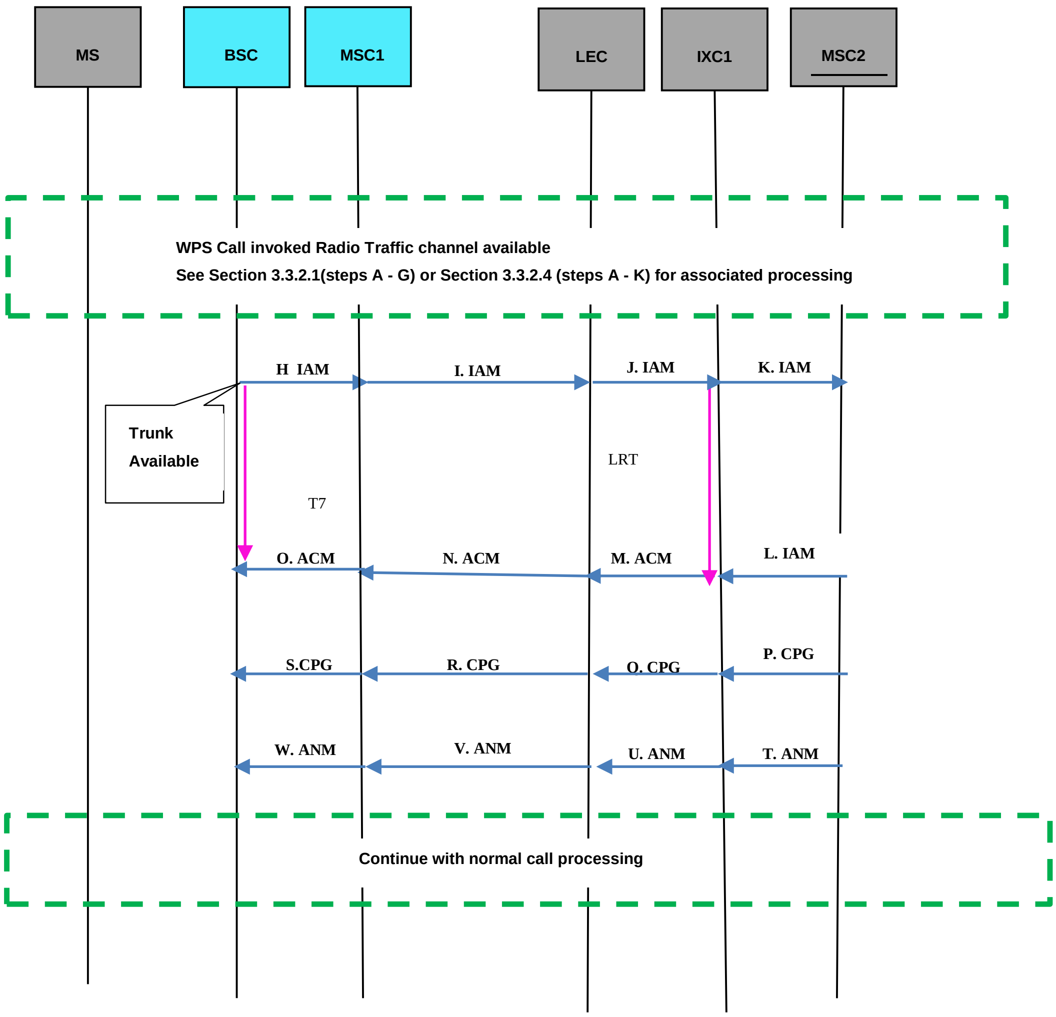

Figure 12. NS/EP call Progression – Successful call setup.

The sequence of events depicted in Figure 12 is explained in detail letter by letter. The call flow assumes trunk resources are available at originating MSC during call setup. Steps A-G refer section 3.3.2.1 if radio traffic channel is available or section 3.3.2.4 A-K if radio traffic channel is not available.

H. MSC builds IAM with calling party category as NS/EP and precedence parm and sends it to LEC.

I. LEC routes call to IXC by forwarding IAM sent by MSC

J. IXC translates and identifies call needs to terminate to MSC. Forwards IAM message to MSC

K. MSC responds back with ACM with BCI parameters indicating call is delayed.

L-O ACM is propagated back to originating node

P-S MSC sends CPG back to originating node as multiple ACM is not allowed.

T-W ANM is sent back to Originating node.

As explained, above sequence of events enables WPS call to be setup successfully on propagating nodes which is wireline network.

3.3.2.4 Priority Radio Resource Queuing

When a Priority Service call encounters a “no radio available” condition in the call path involving an access or egress air-interface, or both, and,
- at call origination upon recognition of the Priority Service dialing pattern, the Priority Service call is queued in the cell serving the calling party and processed for the next available radio channel in that cell in accordance with the caller’s priority level and call initiation time.
- at call termination upon recognition of a priority call indication in an incoming call, the Priority Service call is queued in the cell serving the called party and processed for the next available radio channel in that cell in accordance with the call’s priority level and arrival time.

WPS FOC (WPS FOC 2003) states queuing can be done at any node BSC or MSC and its vendor’s implementation specific. This design option assumes queuing is done on MSC. Queued call is retried for resources and the call remains in the queue for value of queue timer which is configurable. Once the MS sends Origination messages or responds to page it starts T42 timer expiry of which MS can return to idle state. MS is expected to tune to channel in this period. WPS calls are queued for resources and this can delay traffic channel acquiring. To avoid MS to transfer back to idle state T42 timer has to be reset. Status Request/Status response message has been used for this purpose. When WPS call is queued for resources it may experience delay and NS/EP personnel can end the call to try again, which can make the network more congested. To avoid such situation, Feature Notification message is sent which will display “QUEUED” on the screen. Table *6* shows CDMA parameters set for Feature Notification Message by MSC

Table 6. CDMA Parameters for Feature Notification Message.

Field	Description/Value	Field Code
SIGNAL_TYPE	Tone Signal	0
ALERT_PITCH	Medium pitch (standard alert)	0
SIGNAL	Pip Tone: four bursts of 480 Hz tone (0.1 s on, 0.1s off)	1010

DISPLAY	Display (=Queued) (each character represented by 8 bits)	Field length = 6 octets (1 character per octet)
RELEASE	Origination completion indicator [The base station sets this field to ‘1’ if this message is used to complete an origination request from the mobile station; otherwise, the base station sets this field to ‘0’.]	0

The goal of WPS is to provide a priority service to NS/EP leadership and key Personnel, still there can be a significant impact on public use of CMRS radio capacity if personnel are concentrated. Hence FCC R&O (FCC R&O, 1998) recommended Service Provider to ensure that a reasonable amount of CMRS radio capacity is available for public use. Design has to be in such a way WPS calls are not denied as it defies goal of priority service at the same time public calls are not starved. To ensure this Hard Public Use Reservation by Departure Allocation (H-PURDA) algorithm is applied on a cell sector basis. The key parameter of the H-PURDA algorithm is the desired ratio of call allocation between NS/EP call requests (incoming NS/EP as well as outgoing WPS) and public calls (incoming as well as outgoing). Based on H-PURDA algorithm WPS calls are served or put in the queue.

Figure 13 depicts Successful WPS Call Origination with Radio resource queuing.

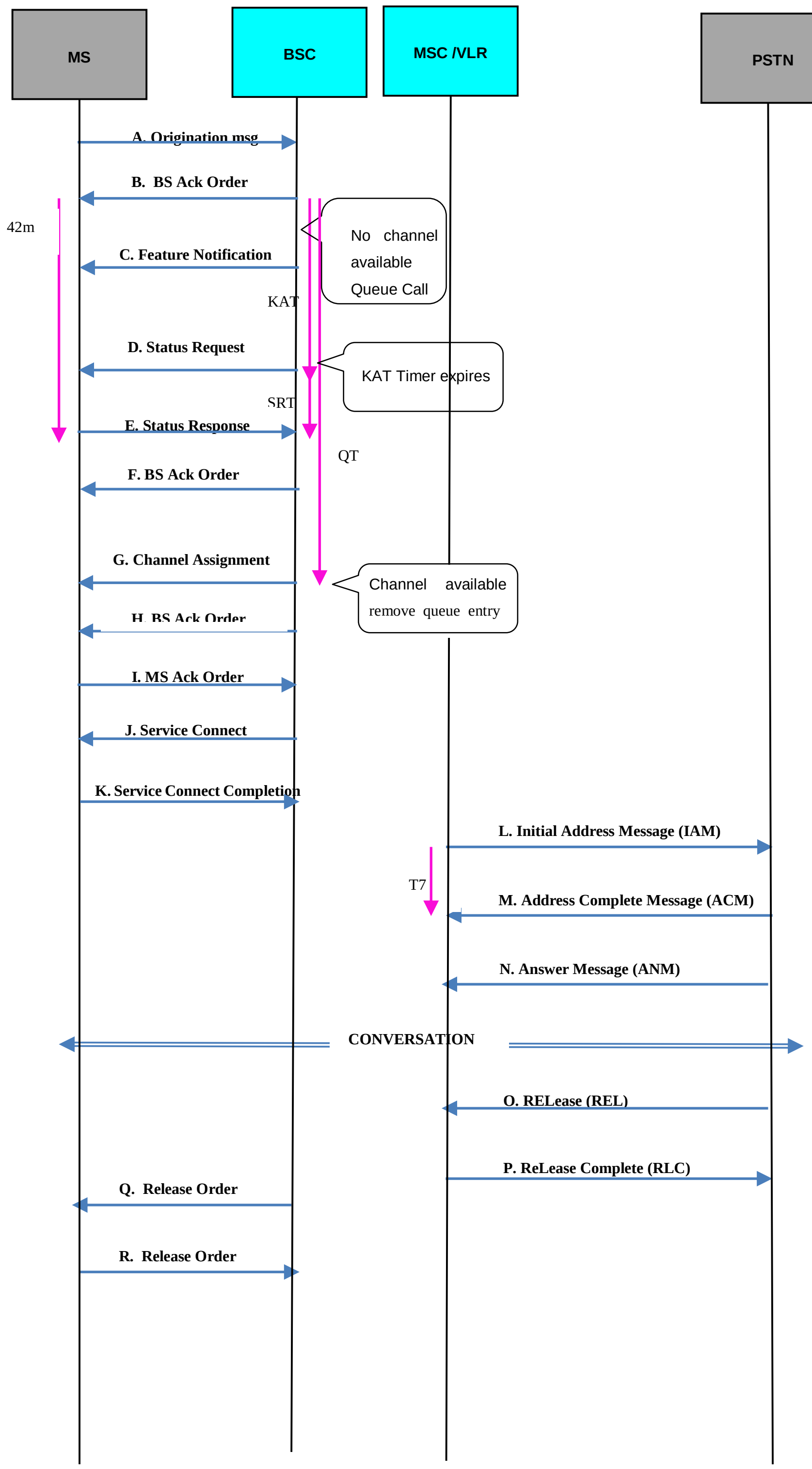

Figure 13. Successful WPS Call Origination – With Queuing for Radio Traffic Channel. (WPS FOC, 2004:4-8)

A-B Same as described in steps A and B of Section 3.3.2.1

C. The MSC determines (based on the *272 prefix as the leading dialed digits within the *Origination Message*) that this is a WPS invocation. The MSC verifies that the caller is subscribed to WPS, based on the profile information previously obtained from the HLR (as described in step G of Section 3.3.1), and uses this profile information to determine the priority associated with that Service User. If no radio resources are available, the BS/MSC queues the originating WPS request based on the WPS queue entry time and the call priority level (as determined based on the Service User's profile) and starts the QT timer.

The BS/MSC then sends a *Feature Notification Message* to the MS on the Paging Channel, confirming that the WPS call request has been queued. The *Feature Notification Message* includes the field RELEASE set to 0, the information record DISPLAY set to "Queued" and the information record SIGNAL with the signal type set to 00 (Tone) and the signal code set to 001010 (Pip tone on).

D. If timer KAT expires before radio resources become available, the BS/MSC sends a Status Request Message to the MS. The BS/MSC starts a timer, herein referred to as the Status Request Timer (SRT), while waiting for a Status Response Message.
E. On receipt of the Status Request Message, the MS cancels timer T_{42m} and starts an access attempt by sending a Status Response Message on the Access Channel to the BS/MSC.
F. On receipt of the *Status Response Message,* the BS/MSC cancels the SRT timer and sends a *Base Station Acknowledgment Order* to the MS. The MS again starts timer T42m. The BS/MSC starts timer KAT.

NOTE: *The BS/MSC transmits a Base Station Acknowledgment Order to the MS to acknowledge the receipt of the Status Response Message if no message directed to the MS (e.g., Channel Assignment Message) is available within ACC_TMO x 80 ms after the receipt of the Status Response Message.*

NOTE: *Steps D through F could be repeated several times.*

G-K. When a radio traffic channel becomes available to serve this WPS call request, and the BS/MSC is not waiting for a *Status Response Message*, the BS/MSC initiates procedures to assign that radio traffic channel. This processing is as discussed in steps C through G of Section 3.3.2.1. If the BS/MSC is waiting for a *Status Response Message*, the BS/MSC must first receive the *Status Response Message* before initiating procedures to assign that radio traffic channel.

L. The BS/MSC uses the dialed digits, excluding the *272 prefix, to determine the intended destination for the call. The call is subsequently treated as an NS/EP call. See the corresponding call progression treatments described in the call flows in Section 3.3.2.3.

The call flow in Figure 14 illustrates successful NS/EP call termination.

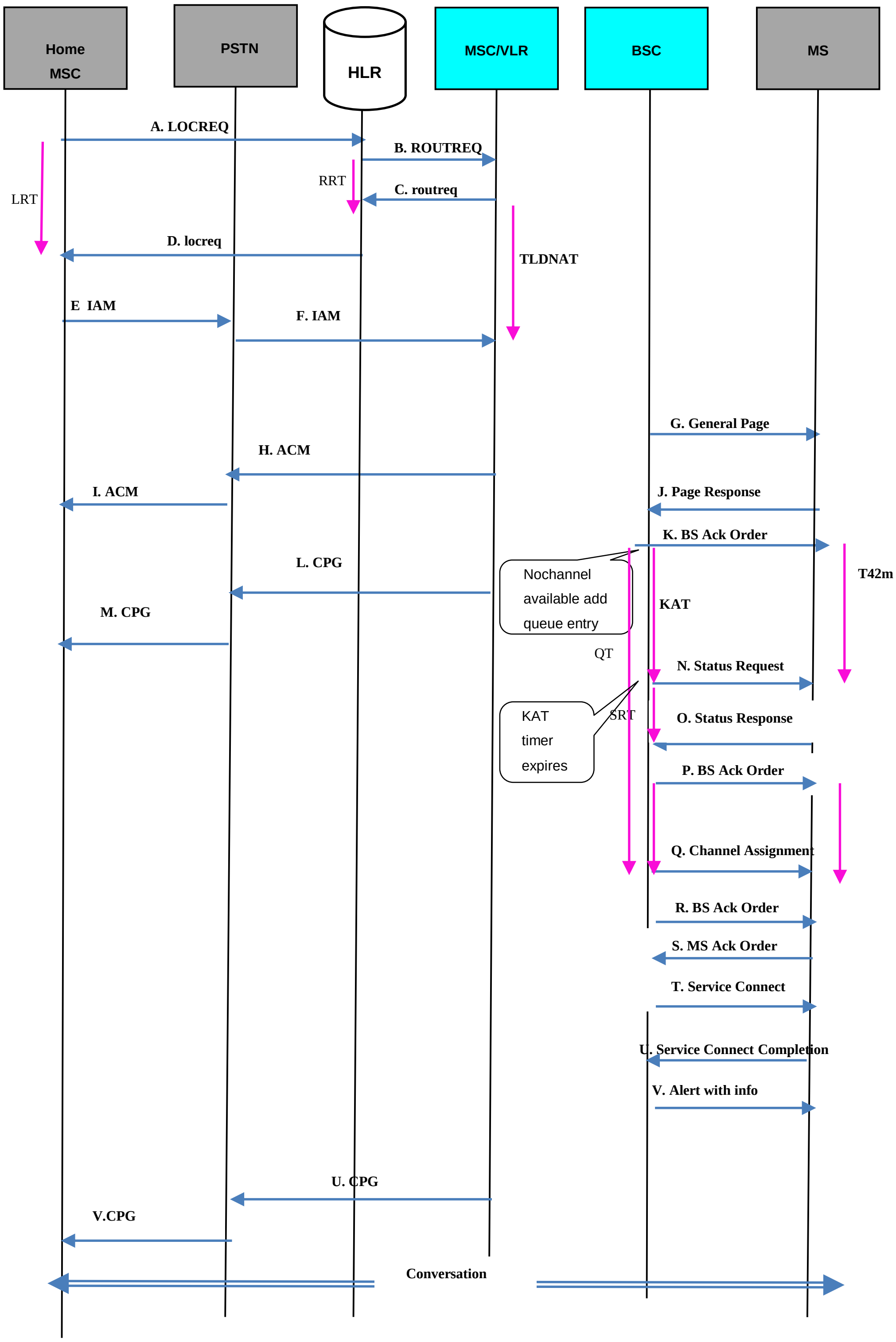

Figure 14. Successful NS/EP Call Termination – With Queuing for Radio Traffic Channel. (WPS FOC, 2004:4-17)

The assumption in Figure *14* is radio traffic channels are not available when the incoming NS/EP call is received by the terminating BS/MSC.

A-K. Same as described in steps A through K of 3.3.2.2

L. On receipt of the *Page Response Message* from the MS, the BS/MSC determines that no radio traffic channel is available. The BS/MSC places the incoming call request on the WPS queue based on the call priority level and queue entry time, starts the QT timer, and starts timer KAT. The BS/MSC sends an ISUP *CPG* message to the PSTN. The ISUP *CPG* message includes the Called Party's Status Indicator field in the Backward Call Indicators parameter set to binary value 11("excessive delay").

M. The PSTN sends an ISUP *CPG* message to the Home MSC.

N. If timer KAT expires before a radio traffic channel becomes available, the BS/MSC sends a *Status Request Message* to the MS to cancel timer T42m at the MS. The BS/MSC starts the SRT timer, while waiting for a *Status Response Message*.

O. On receipt of the *Status Request Message*, the MS cancels timer T42m and sends a *Status Response Message* on the Access Channel to the BS/MSC.

P. On receipt of the *Status Response Message,* the BS/MSC cancels the SRT timer and sends a *Base Station Acknowledgment Order* to the MS. The MS again starts timer T42m. The BS/MSC starts timer KAT.

NOTE: The BS/MSC transmits a *Base Station Acknowledgment Order* to the MS to acknowledge the receipt of the *Status Response Message* if no message directed to the MS (e.g., *Channel Assignment Message*) is available within ACC_TMO x 80 ms after the receipt of the *Status Response Message*.

NOTE: Steps N through P could be repeated several times.

Q. When a radio traffic channel becomes available to serve the queued incoming NS/EP call request, and the BS/MSC is not waiting for a *Status Response Message*, the BS/MSC begins sending null Traffic Channel data over that channel, sends a *Channel Assignment Message* to the MS on the Paging Channel, cancels the QT timer, cancels timer KAT, and removes the call request from the WPS queue. In this scenario, timer T42m is still running at the MS and the MS is in the Page Response Substate of the System Access State. When the MS receives the *Channel Assignment* message, it cancels timer T42m.

***NOTE:** If timer T42m expires before a radio traffic channel becomes available, the MS moves to the Idle State.*

NOTE: *If the BS/MSC is waiting for a Status Response Message when a radio traffic channel becomes available to serve the queued incoming NS/EP call request, the BS/MSC must first receive the Status Response Message before initiating procedures to assign that radio traffic channel.*

R-V. The radio traffic channel is assigned and the terminating MS is alerted, as described in steps M through Q of Section 3.3.2.2

W-X. Optionally, the terminating MSC sends an ISUP *CPG* message to the PSTN and the PSTN sends an ISUP *CPG* message to the Home MSC.

The call processing flow proceeds normally beyond this point. See the description for the call flow in Section 3.3.2.3 (steps T through AB).

3.3.2.5 Priority Call Trunk Queuing

After recognition as NS/EP calls by the call processing node, WPS and GETS calls are marked as NS/EP calls for continued call processing. When signaled over SS7, both WPS and GETS calls are signaled with the Calling Party Category (CPC) of the Initial Address Message (IAM) set to NS/EP Call. This is also called the High Probability of Completion (HPC) code point. NS/EP calls are also signaled with an MTP priority of "1". WPS calls also includes the WPS priority level of the subscriber indicated in the Precedence Parameter of the ISUP IAM.

When an NS/EP call arrives via SS7 signaling at an MSC for termination, it is recognized as NS/EP by the IAM having the CPC set to HPC. The MSC provides the NS/EP call queuing for radio channel resources if needed. An NS/EP call with an SS7 ISUP IAM Precedence Parameter conveying the WPS priority level of the call will have the priority applied by the terminating MSC. An NS/EP call without an SS7 IAM Precedence Parameter is assigned a default priority level. The queuing improves the likelihood of success for terminating NS/EP calls.

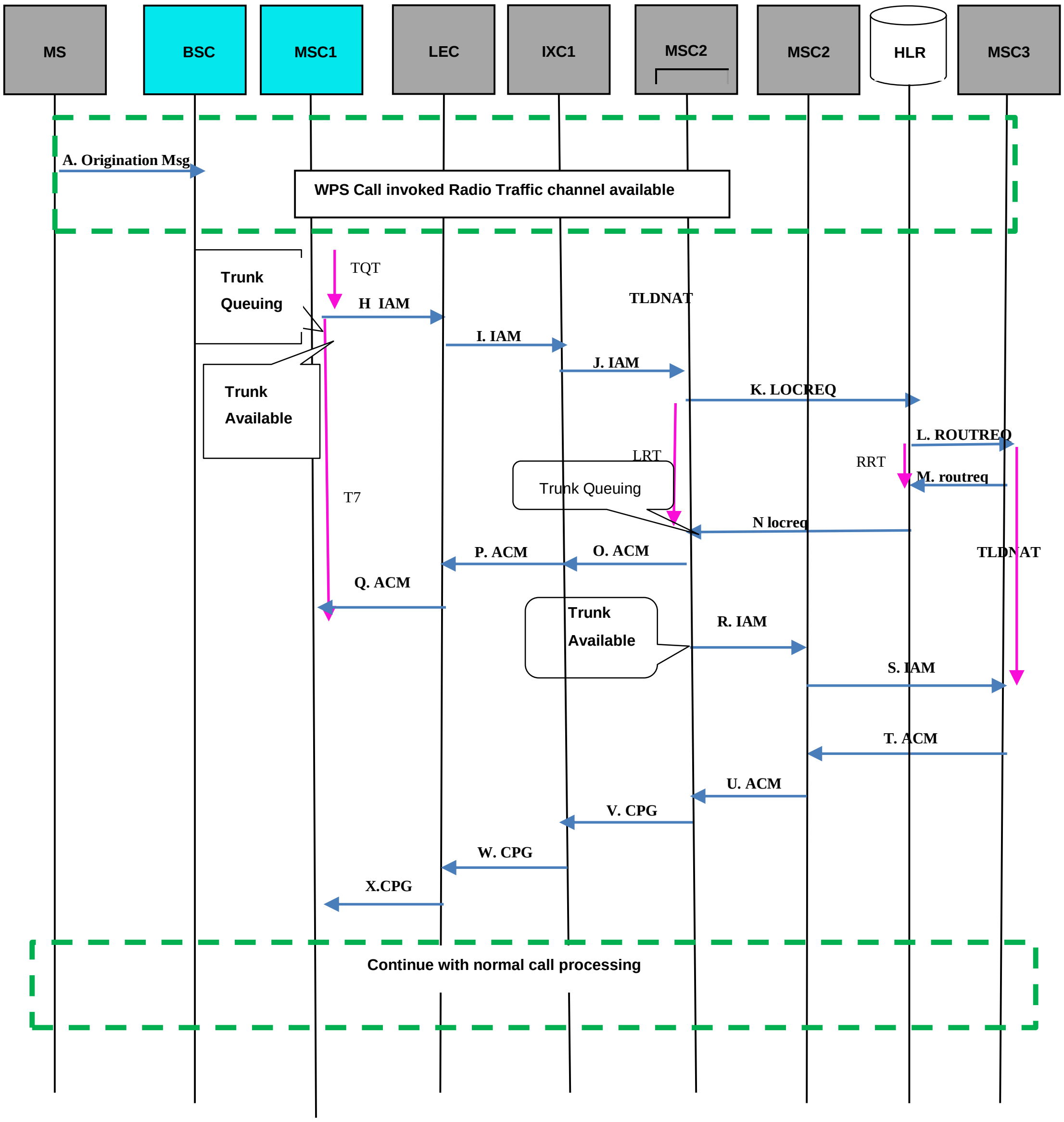

Figure 15. Trunk Queuing at Originating MSC and Terminating IXC - Successful Call Setup. (WPS FOC, 2004:4-22)

A-G. A Service User dials *272 + DN. This scenario assumes the DN is not a toll-free number. The MS sends an Origination Message to the BS/MSC (via the Access Channel), containing the dialled digits. A radio traffic channel is subsequently assigned to the WPS call request. See Section 3.3.2.1 (steps A through G) and Section 3.3.2.4 (steps A through K) for descriptions of the associated processing under various conditions.

H. When a radio traffic channel is assigned for the originating WPS call request, MSC1 attempts to route the call toward its destination. Since this WPS call is marked as an NS/EP call, MSC1 attempts to extend the call toward an HPC capable IXC, in order to afford it with special call completion capabilities (as discussed in Section 3.3.2.3). In this case, MSC1 does not have direct trunk groups connecting to an HPC-capable IXC, so the MSC translations are set up to route NS/EP calls to a LEC Access Tandem (AT). For the scenario depicted in

, MSC1 encounters an all-trunks-busy condition on the trunk group to the LEC AT and initiates trunk queuing. The MSC starts an associated Trunk Queuing Timer (TQT).

When a trunk becomes available to the LEC AT, MSC1 attempts to seize that trunk, cancels timer TQT, starts ISUP timer T7, and sends an ISUP IAM message. The ISUP IAM message includes the CPC parameter set to “NS/EP call” and, if the MSC is configured to include the Precedence parameter, the Precedence parameter is set based on the originating Service User’s priority level. In addition, MSC1 includes the Transit Network Selection (TNS) parameter, used to identify an HPC-capable IXC (“IXC1” in this example) for subsequent routing. The ISUP TNS parameter in the ISUP IAM message contains a carrier's identification code. The purpose of this parameter is to indicate to an intermediate node or a network what carrier is to be selected to route the call. If the TNS parameter is present in the incoming ISUP IAM message to a LEC AT, the dialled digits will not be used for routing, i.e., the carrier identification code in the TNS parameter will be used for routing the call.

I. After receiving the ISUP IAM message, the LEC AT sends an ISUP IAM message to IXC1. The ISUP IAM message includes the Precedence parameter (if available and configured) and the CPC parameter, as received in the incoming message.

J. After receiving the ISUP IAM message, IXC1 determines that the call needs to be routed to MSC2 (i.e., to the called party’s Home MSC). IXC1 sends an ISUP IAM message to MSC2, including the Precedence parameter (if available and configured) and the CPC parameter, as received in the incoming message.

K. MSC2 sends a Location Request (LOCREQ) message with a WPSCallIndicator parameter to the called party’s HLR and starts the LRT timer, waiting for the associated response message.

L. The HLR determines that the target MS is roaming, sends a Routing Request (ROUTREQ) message with a WPSCallIndicator parameter to the MSC that is currently serving that MS (i.e., MSC3), and starts the RRT timer, waiting for the associated response message.

M. MSC3 assigns a Temporary Local Directory Number (TLDN) for this call and sends a Routing Request (routreq) RETURN RESULT message to the HLR. MSC3 starts the TLDN Association Timer (TLDNAT) when the TLDN is assigned for call delivery. For NS/EP calls that include the WPSCallIndicator parameter (as discussed in step L above), the TLDNAT is set to a higher value than for non-NS/EP calls.

N. When the HLR receives the routreq message, it cancels timer RRT and sends a Location Request (locreq) RETURN RESULT message to MSC2, including the TLDN as received above.

O. When it receives the locreq message, MSC2 cancels timer LRT. For this scenario, MSC2 determines that this call needs to be routed via IXC2. However, it finds that no trunks are currently available to IXC2. Therefore, MSC2 queues for an outgoing trunk, starts timer TQT, and sends an ISUP ACM message back to the preceding switch (i.e., to IXC1). The ISUP ACM message includes the Called Party's Status Indicator field in the Backward Call Indicators parameter set to binary value 11 ("excessive delay").

P. IXC1 receives the ISUP ACM message and sends an ISUP ACM message on to the LEC AT.

Q. The LEC AT receives the ISUP ACM message and sends an ISUP ACM message on to MSC1. Upon receipt of the ISUP ACM message, MSC1 cancels ISUP timer T7.

R. When a trunk becomes available, MSC2 cancels timer TQT, starts ISUP timer T7, and sends an ISUP IAM message to IXC2, including the CPC and (if available and configured) the Precedence parameters (as received in step J).

S. After receiving the ISUP IAM message, IXC2 determines (based on the Called Party Number, populated with the TLDN previously assigned by MSC3) that the call needs to be routed to MSC3. IXC2 sends an ISUP IAM message to MSC3, including the CPC parameter and (if available and configured) the Precedence parameter, as received in the incoming message.

T. MSC3 receives the ISUP IAM message, extracts the called DN, and determines that this corresponds to the TLDN that it had previously assigned. MSC3 cancels timer TLDNAT, determines the corresponding MSID associated with that TLDN, and attempts to complete the call to that MS. MSC3 returns an ISUP ACM message to IXC2.

Note that further details concerning the processing that is performed by the terminating MSC (MSC3) are discussed in Section 4.4.

U. Upon receipt of the ISUP ACM message, IXC2 sends an ISUP ACM message to MSC2.

V-X. MSC2 receives the ISUP ACM message, cancels ISUP timer T7 and, having already sent an ISUP ACM message to IXC1 in step O, maps this to an ISUP Call Progress (CPG) message that is sent to IXC1. ISUP CPG messages are subsequently relayed to the LEC AT and on to MSC1.

Subsequent call processing continues, similar to the processing illustrated in steps J through N of Section 3.3.2.2.

3.3.3 WPS Enhanced Overload Performance

During emergency there can be a mass calling event due to which networks get overloaded. The reasons for this may be exhaustion of resources, processing delay etc. During such high traffic conditions two areas of concerns observed are,

1. Overload at the cell sector Access Channel resulting in significant (Access Channel) throughput degradation that eventually leads to radio access denial. (termed as "Access Denial")
2. Real-time overload at the various nodes that trigger overload controls and message shedding. This impacts the overall system throughput performance and could be considerable. (termed as "Overload Message Shedding")

This resulted in WPS users being denied access channel to make priority calls and receive high probability of call completion features. Even if access channel was obtained, feature recognition happens at MSC and by that time call has progressed through various intervening nodes where it can get subjected to overload controls. Ultimately WPS user will not get any priority treatment even if solution exists to handle the same. To mitigate this risk FCC issued another Industry Standard called WPS Enhanced Overload Performance to ensure WPS calls are immune to such conditions. (CDMA IR WPS Overload, 2009)

To overcome Access Channel overload, assignment of WPS users to specified *access class* solution was used. Industry standards (reference 3GPP2 C.S0003-0, C.S0004-0, C.S0005-0) has defined access class 0-16 which can be assigned to mobiles. WPS users were provisioned with access class 11. For overload shedding generally network tries to shed new calls before taking down existing calls. The solution CDMA NS/EP call origination message shedding is to identify NS/EP messages early in the signaling process, and then use the identification to make NS/EP calls exempt from the overload message.

This chapter explained the WPS call flows for major call processing scenarios and action on each nodes to provide priority. With this background information on WPS design the next chapter will focus on enhanced circuit switch fallback.

4 Enhanced Circuit Switch Fall Back

Circuit Switch Fall Back being interim solution for telecom operators to meet time to market pressures for voice in LTE networks, 3GPP came up with several options to meet reduced call setup and reliability issues. One of the solution is Enhanced Circuit Switch Fall Back. This was introduced in 3GPP Release 9. The enhanced 1xCSFB uses 1xRTT handover signaling tunneled between the UE and the 1xRTT network. Enhanced 1xCSFB is a UE capability named e-CSFB-1XRTT (3GPP TS 36.306, 2010). As the network advertises support for enhanced CSFB, enhanced CFSB User register in 1XRTT domain using S102 tunnel.

As per 3GPP TS 23.272
“Enhanced CSFB to 1XRTT is supported for UEs with both single Rx and dual Rx configuration (TS 36.331).]). UEs with single Rx configuration are not able to camp in 1xRTT when they are active in E-UTRAN. The network therefore provides mechanisms for the UE to perform registration to 1xRTT, receive 1xRTT paging, SMS etc. while the UE is in E-UTRAN. UEs with dual Rx configuration can camp in 1xRTT while they are active in E-UTRAN, they may however not be able to stay in E-UTRAN when they handle a CS call and/or perform registration signalling, and/or sending or receiving SMS in 1xRTT. ”

Figure 16 shows protocol stack at each node and S102 tunnel for enhanced CSFB.

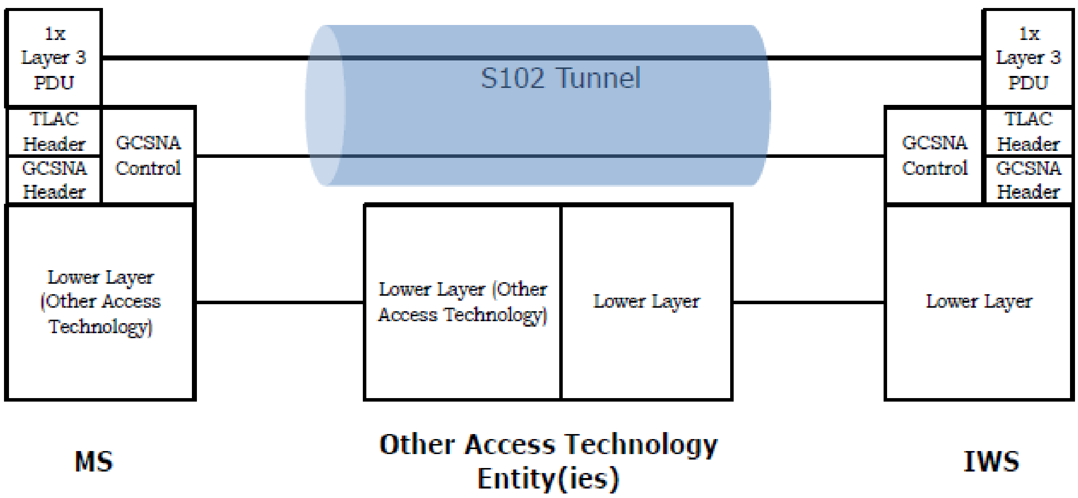

Figure 16. Protocol Architecture Reference Model (cdma2000 Technology Workshop June 2012).

As shown in Figure *16* Generic Circuit Services Notification Application (GCSNA) Protocol supports signalling transactions for cdma2000 1x circuit-switched services between the mobile station and the 1xCS IWS through any radio access technologies which provides a tunnel between the mobile station and IWS. This protocol provides 1x layer 3 Protocol Data Unit (PDU) encapsulation with Tunnelled Link Access Control (TLAC) and further encapsulated with GCSNA header.

4.1 Enhanced CSFB Mobile Origination Call Flow

Figure 17 describes the mobile originating call procedures for the enhanced CS Fallback to 1xRTT.

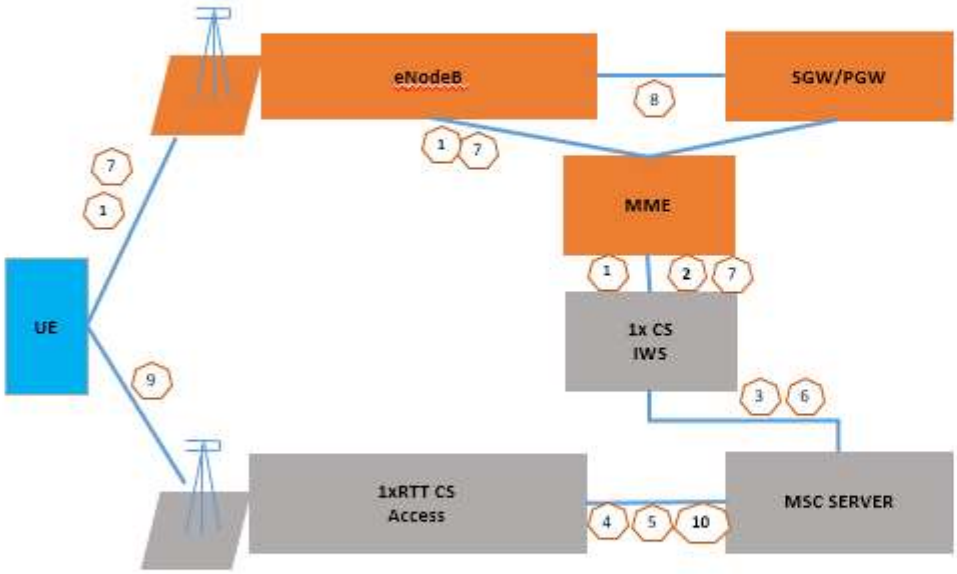

Figure 17. Enhanced CS fallback to 1xRTT MO Call

As shown in Figure 17 sequence of events for the call flow is explained in detail as a numbered list. The call flow details is an extract from 3GPP (TS 23.272 Figure B.2.3a.2-1, 2015: 80). UE is E UTRAN attached and registered with 1xRTT CS with enhanced CS fallback to 1xRTT capability indication to E-UTRAN. UE makes a decision to perform a mobile originated CS call. UE sends Extended Service request message to request CS fallback to 1xRTT and E-UTRAN initiates handoff preparation procedures towards the MS/UE. For simplicity concurrent PS Handover is not considered.

1. MS/UE sends an Origination message to the IWS using GCSNA protocol over E-UTRAN

2. 1x CS IWS sends an A21-Ack message to the MME
3. 1x CS IWS creates a CM Service Request message, sends it to the MSC
4. MSC decodes origination message determines its call from E-UTRAN. Sends Handoff request to Target BSC with the MS Information Record IE and the IS-95 Channel Identity IE or the IS-2000 Channel Identity IE present, based on if the corresponding MS Information Record IE and IS-2000 or IS-95 Channel Identity IE were present in the Origination message sent from IWS.

5. Upon receipt of the Handoff Request message from the MSC, the target BS allocates appropriate radio resources as specified in the message. As the Handoff Request message can contain multiple cell(s) specified, the target BS can also choose to set up multiple cell(s) for the handoff request. The target BS sends null forward traffic channel frames to the MS/UE. The target BS sends a Handoff Request Acknowledge message to the MSC

6. The MSC prepares to switch the MS/UE from the IWS to the target BSC and sends a Handoff Command message to the IWS. MSC includes the service configuration records it received in the Handoff Request Acknowledge message

7. The IWS sends a Universal handoff Direction Message(UHDM) to the MS/UE to instruct it to handoff to 1x system

8. E-UTRAN will trigger MME to suspend the UE context

9. The MS/UE retunes to the 1x radio network and performs traffic channel acquisition with the 1x BS. The 1x BS connects the bearer path. The MS/UE sends a 1x Handoff Completion Message to the 1x BS.
10. 1x BS sends a Handoff Complete message to the MSC

The call flow explains Enhanced CSFB Mobile Origination and messages exchanged between various nodes.

4.2 Enhanced CSFB Mobile Termination

Figure 18 describes Mobile Terminating Call procedures for the enhanced CS Fallback to 1xRTT.

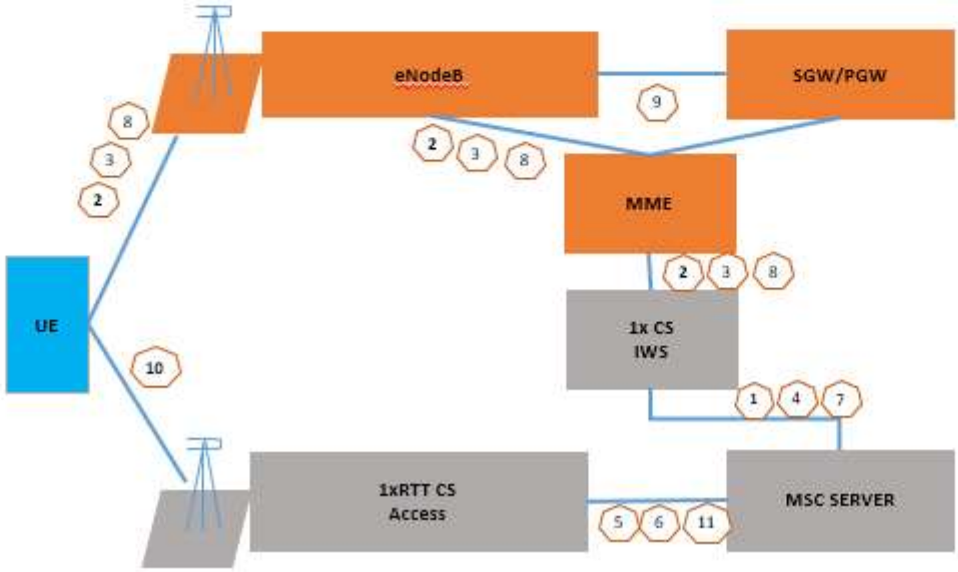

Figure 18. Enhanced CS fallback to 1xRTT Mobile Termination Call Flow.

As shown in Figure 18 sequence of events for the call flow is explained in detail as a numbered list. The call flow details is an extract from 3GPP (TS 23.272 Figure B.2.3a.2-1, 2015).

UE is E-UTRAN attached and pre-registered with 1xRTT CS with enhanced CS fallback to 1xRTT capability indication to E-UTRAN.

1. The MSC determines that an incoming call terminates to an MS/UE within its serving region and sends the Paging Request message to the IWS-1xBS to initiate a mobile terminated call setup scenario.

2. The IWS-1xBS sends a Page Message to the MS/UE via GCSNA through E-UTRAN.

3. The MS/UE sends a Page Response message to the IWS-1xBS via GCSNA through E-UTRAN.

4. The IWS-1xBS constructs the Paging Response message, and places it in the Complete Layer 3 Information message, sends the message to the MSC

5. The MSC sends a Handoff Request message to the target BS with the MS Information Record IE and the IS-95 Channel Identity IE or the IS-2000 Channel Identity IE present, based on if the corresponding MS Information Record IE and IS-2000 or IS-95 Channel Identity IE were present in the Origination message.

6. Upon receipt of the Handoff Request message from the MSC, the target BS allocates appropriate radio resources as specified in the message. As the Handoff Request message can contain multiple cell(s) specified, the target BS can also choose to set up multiple cell(s) for the handoff request. The target BS sends null forward traffic channel frames to the MS/UE. The target BS sends a Handoff Request Acknowledge message to the MSC.

7. The MSC sends a Handoff Command message to the IWS-1xBS. The MSC shall include in the Handoff Command message the service configuration records it received in the Handoff Request Acknowledge message.

8. The IWS-1xBS sends a handoff direction message to the MS/UE via the E-UTRAN using GCSNA, to instruct the MS/UE to handoff to the 1x system.

9. The S1 release procedure and PS service suspend procedure are described in 3GPP TS 23.272

10. The MS/UE tunes to the 1x radio network and performs traffic channel acquisition with the target BS. The MS/UE sends a 1x Handoff Complete Message to the target BS.

11. The target BS sends a Handoff Complete message to the MSC.

The call flow explains Enhanced CSFB Mobile Origination and messages exchanged between various nodes.

5 Proposed Solution

This section describes the solution of this study. It proposes impacts to the nodes in the LTE Access and CDMA System to design a CSFB WPS call. This section starts by analysing WPS feature requirements and scenarios discussed in section 2 and presents a WPS CSFB call flow and impacted functions in the system to handle this call flow. This solution assumes that the changes are applicable for vendors who has chosen a WPS queuing at MSC.

5.1 Downloading of CS Domain Priority Information Procedure

MPS is a subscription feature and subscription details are available in HSS. A service user's EPS subscription information contains an indication of the users 1xRTT CS domain priority status, i.e. a MPS CS priority. This information is downloaded to MME during the attach procedure. During call origination, a MPS CS priority is used by MME to determine if a call has to be given priority treatment or not while setting up the resource. In case of mobile termination, WPS priority stored in the HLR and downloaded to VLR as explained in section 3.3.2.2 is used by the MSC.

MPS Priority is defined as follows in 3GPP TS 29.272 (see Table 7). The MPS-Priority AVP is of type Unsigned32 and it shall contain a bit mask. The meaning of the bits are as defined as below.

Table 7. MPS-Priority reprinted from (TS 29.272).

Bit	Name	Description
0	MPS-CS-Priority	This bit, when set, indicates that the UE is subscribed to the eMLPP or 1x RTT priority service in the CS domain.
1	MPS-EPS-Priority	This bit, when set, indicates that the UE is subscribed to the MPS in the EPS domain.
Note: Bits not defined in this table shall be cleared by the sending HSS and discarded by the receiving MME or SGSN.		

NOTE: The HSS derives the information for MPS-CS-Priority from the eMLPP Subscription Data as defined in the (3GPP TS 29.002, 1999:85) or 1x RTT priority service.

Figure 19 shows the attach procedure in which priority information is downloaded to MME.

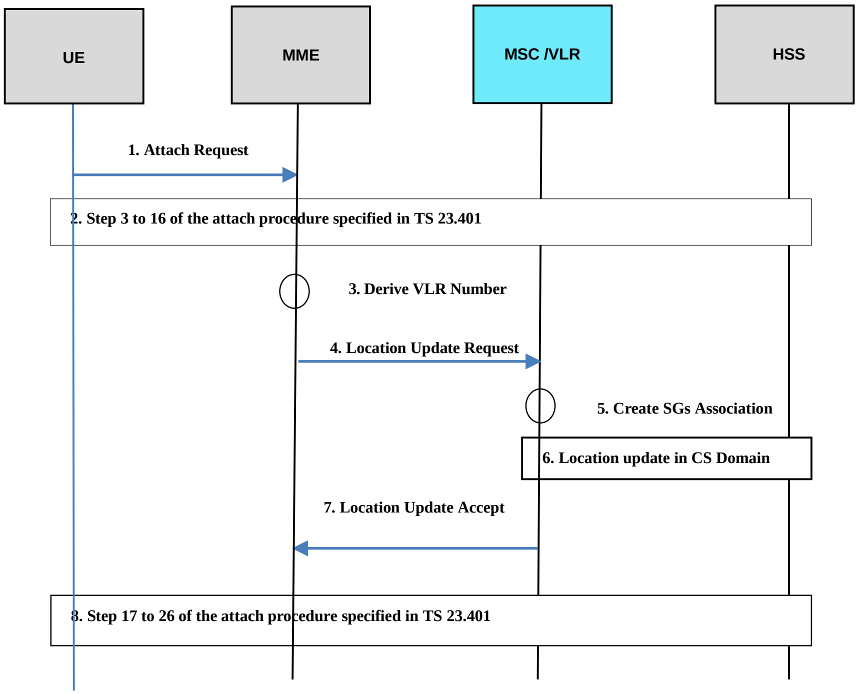

Figure 19. 1xRTT CS registration procedure (from TS 23.272:72).

Steps 1-6 are performed as defined in TS23.272. If the UE has subscribed the eMLPP service in the CS domain, MME obtains the priority indication in the subscription data from the HSS via Update Location Request Ack message. The CS priority indication is derived from the eMLPP service subscription.
Step 7 the VLR responds with Update Location Accept (TMSI) to the MME.

These procedures indicate priority information downloaded to control nodes like MME and MSC which are involved in decision making process.

5.1.1 Impacted Functions in System

The HSS provides the CS priority indication to the MME during the subscription data update procedure if the user subscribes the 1xCS priority service in the CS domain.

HLR provides WPS priority indication to MSC during location update procedure if the user is subscribed to WPS (details refer Figure *8*). Currently operators who already support WPS on CDMA system have the functionality of WPS priority downloaded to VLR. To support CSFB WPS termination no additional enhancement is required. Existing HLR and VLR WPS functionality can be reused.

5.2 CSFB WPS Call Processing Call Flows

This section illustrates CSFB WPS call flows describing how calls are processed at various nodes of LTE and CDMA system and what are special messages and parameters used to identify its WPS call and propagate the same so subsequent nodes can provide priority treatment. This section discusses only the success scenarios.

5.2.1 Priority Call Origination

When a UE originates the priority call it sets establishment cause as ”highpriorityaccess”. MME upon receiving highpriorityaccess from UE identify it is a priority call invoked by user and verifies the user is authorized to make call by checking MPS CS priority. MME requests eNodeB to prioritize call. Once RRC setup is done call is routed to MSC and the WPS features is invoked.

Figure 20 illustrates high level call flow of Enhanced CSFB WPS Origination.

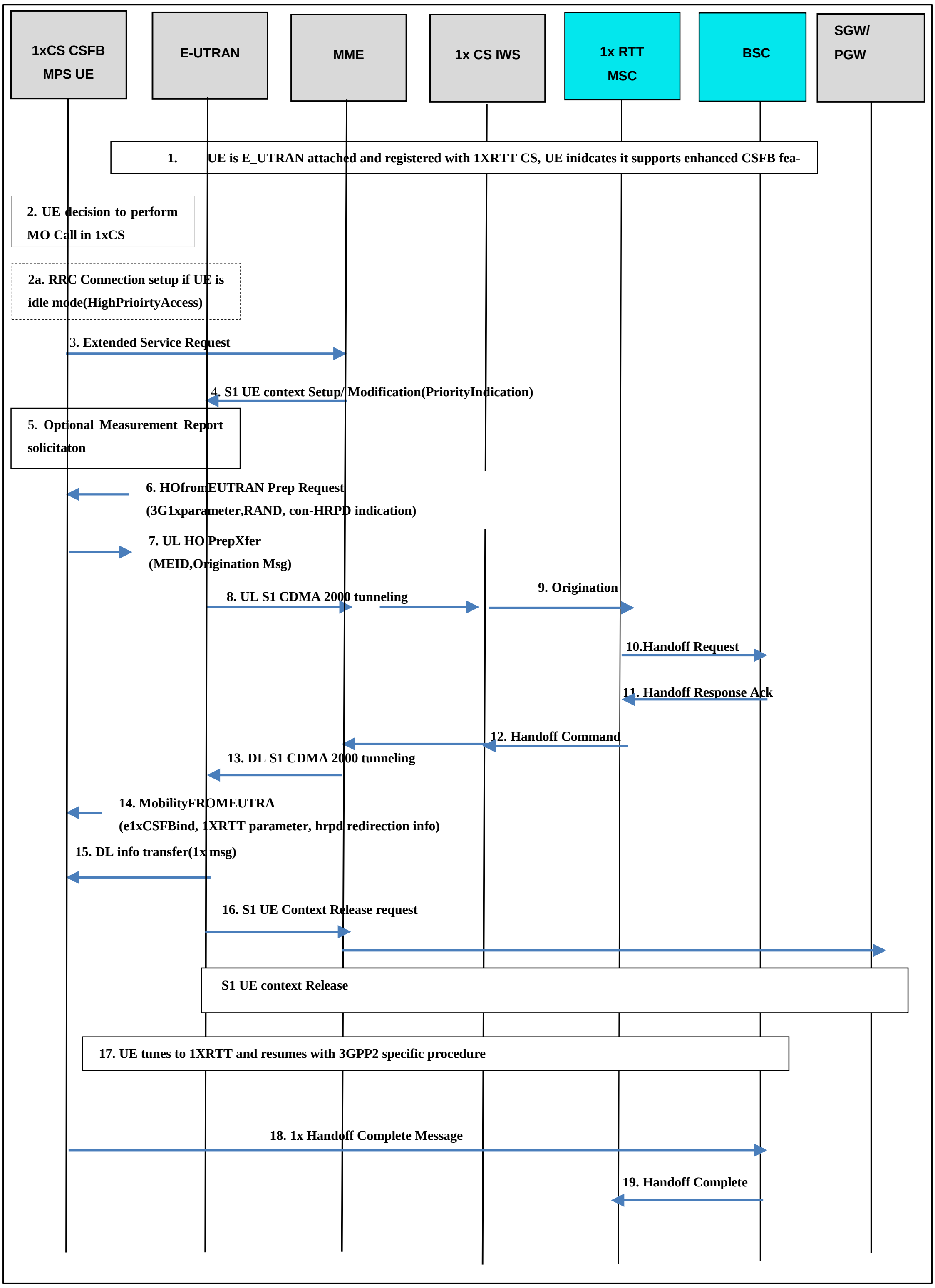

Figure 20. Successful CSFB WPS Call Origination – Radio Resources Available.

As shown in Figure *20* the sequence of events are detailed as numbered list. The call flow assumes radio resources are available. The details are extracted from 3GPP TS23.272 Figure B.2.3a.2-1,2014:80 and MPS, WPS specific information are added.

1. UE is E UTRAN attached and registered with 1xRTT CS as defined in clause B.2.1.1 (3GPP TS 23.272, 2015:72) with enhanced CS fallback to 1xRTT capability indication to E-UTRAN.
2. UE makes a decision to perform a mobile originated CS call

   If the UE is in idle-mode, in order to ensure that the RRC connection is treated with adequate priority the UE sets the establishment cause to HighPriorityAccess.
3. UE sends an Extended Service Request for mobile originating 1xCS fallback to the MME. It does not contain any priority indication.
4. The MME determines that the Extended Service Request requires priority handling based on either (a) the "HighPriorityAccess" establishment cause sent by eNB to the MME in the S1AP message if the MO 1xCSFB call occurred when the UE is in idle-mode, or (b) the CS priority indication in subscription information send by the HSS during the attach procedure if MO 1xCSFB call occurred when the UE is in connected state. The MME sends an S1 UE Context modification (for an active UE) or, UE Context setup (for an idle UE). This message also includes a priority indication.

   According to operator policy the MME may use the CS priority indication to verify the priority handling of the CS Fallback procedure, in the case "HighPriorityAccess" is received in the S1-AP message.
5. E-UTRAN may optionally solicit a 1xRTT measurement report from the UE to determine the target 1xRTT cell to which the CS Fallback will be performed.
6. E-UTRAN sends a HandoverFromE-UTRAPreparation Request message to the UE to start the enhanced 1xCS Fallback procedure. It includes 3G1x Overhead Parameters and RAND value. This message also includes an indication that concurrent HRPD handover preparation is not required.
7. The UE initiates signalling for establishment of the CS access leg by sending UL HandoverPreparation Transfer message which contains the 1xRTT Origination message with WPS Prefix digits and called party number.
8. Messages between MME and 1xIWS are tunnelled using the S102 interface.

9. 1x CS IWS decodes CDMA2000 Origination message and builds Origination message to the MSC.

10. 1XRTT MSC upon receiving Origination messages determines (based on the *272 prefix as the leading dialled digits within the Origination Message) that this is a WPS invocation. The MSC verifies that the caller is subscribed to WPS based on the profile information previously obtained from the HLR as described in step G of Section 3.3.1. MSC uses this profile information to determine the priority associated with that Service User. Once user validation is done it sends Handoff Request message to BSC with target cell list obtained by measurement report sent by E-UTRAN.

11. BSC allocates channel on target cell list sent by the MSC. Sends Handoff Response with list of cells on which the channel is available.

12. MSC sends Handoff command to 1x CS IWS passing all 1XRTT channel information received from RNC.

13. 1x CS IWS encapsulates CDMA2000 Universal Handoff Command with A21 header and sends the message over the link to MME.

14. The E UTRAN sends Mobility from EUTRA Command to the UE with indication that this is for enhanced 1x CS Fallback operation, 1xRTT related information. The 1xRTT information contains 1xRTT messages related to 1x channel assignment and cause the UE to tune to and acquire this 1x channel. This is perceived by the UE as a Handover Command message to 1xRTT.

15. The E-UTRAN sends DL information transfer message, with the embedded 1x message indicating 1xRTT preparation success to the UE.

16. E-UTRAN sends an S1 UE Context Release Request (Cause) message to the MME. Cause indicates that the S1 UE Context Release was caused by CS fallback to 1xRTT. The S1-U bearers are released and the MME starts the preservation and suspension of non-GBR bearers and the deactivation of GBR bearers towards S-GW and P-GW(s). The MME sets the UE context to suspended status.

17. UE tunes to the 1xRTT radio access network and performs 1xchannel acquisition with the 1xRTT CS access (e.g. 1xRTT BSS). A UE supporting enhanced 1xCSFB to 1xRTT for dual receiver/transmitter configuration continues to receive/transmit data on E-UTRAN.

18. UE sends Handoff completion message to BSC.

19. BSC notifies MSC of handoff completion which indicates originator is setup now. MSC continues with call setup and propagates high probability of call completion parameters to subsequent nodes.

The call flow explains how each call processing nodes identify its priority call and enable end to end high probability of call completion.

5.2.1.1 Impacted Functions in System

MME determines whether the CSFB MO procedure needs to be handled preferentially based on 'highpriorityaccess' or MPS CS priority. The MME provides priority indication in S1 AP Initial Context Setup and UE Context Modification Request messages to the eNodeB.

In a congestion situation, the eNodeB uses priority indications to allocate E-UTRAN radio bearer resources with preference over to normal resource requests with no priority indication.

MSC identifies its WPS CSFB call based on digits dialled and user subscription information available in the VLR. User subscription is downloaded during registration described in section 5.1. WPS Prefix DN is a configuration parameter which MSC compares with dialled digits. Once MSC identifies its WPS CSFB call it will store information in per call specific data block. This will be applicable for successful propagation of WPS call or to provide some special treatment during validation pending, unauthorized user scenarios.

5.2.2 Priority Call Termination

When NS/EP call arrives on MSC, MSC determines the user is camping on LTE and pages the user on LTE with prioritized 1x CS paging request. In order to provide priority while paging and establishing radio and S1 connection at MME and eNodeB, MSC needs to forward the priority information to MME. Terminating MSC receives call priority details via ISUP IAM message and this can be passed to MME. Once the UE responds to page via LTE tunnel MSC will try to setup priority call.

Figure 21 illustrates call flow for NS/EP CSFB Termination.

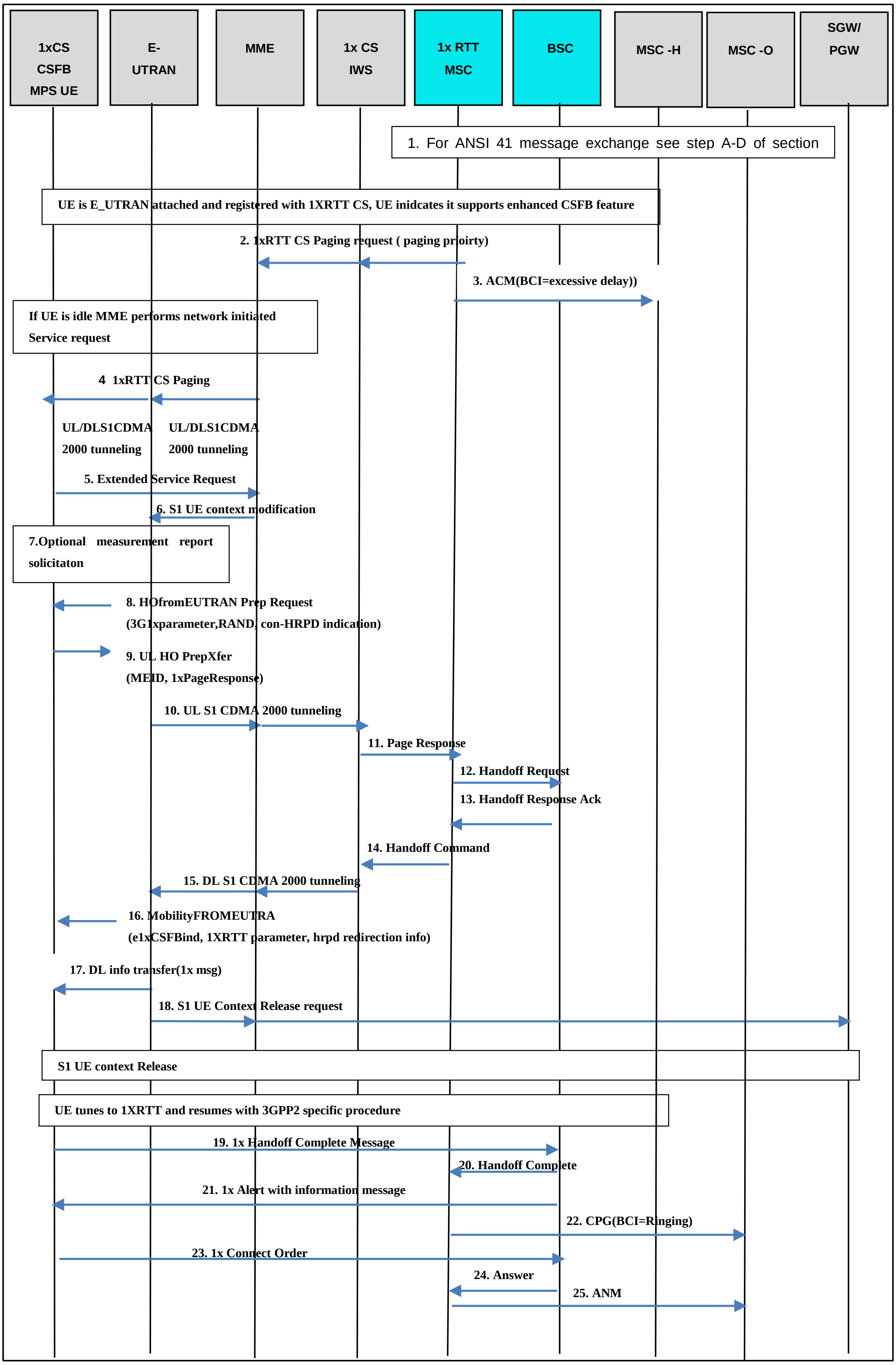

Figure 21. Successful CSFB NS/EP Call Termination – Radio Resources Available.

1. Please refer steps A-D of section 3.3.2.2
2. Terminating MSC upon receiving ISUP IAM with NS/EP parameters mark call as WPS. Since MS/UE is E-UTRAN attached and registered with the MSC, The MSC determines that an incoming call terminates to an MS/UE within its serving region and sends the Paging Request message to the 1x CS IWS to initiate a mobile terminated call setup scenario. The paging request message from the 1xRTT MSC to the IWS will contain a priority value or an emergency indicator as specified in 3GPP2 specification A.S0008-C v3.0 [9] / A.S0009-C v3.0 [10]. The S102 message containing the paging request message sent from the 1xCS IWS to the MME contains a priority value.
3. MSC sends ACM with Backward Call Indicator status as excessive delay indicating call can be delayed.
4. If UE is idle state MME pages UE via GCSNA through E-UTRAN. Pagingprioirty passed to E-UTRAN will enable eNodeB to prioritize
5. UE performs extended service request as per 3GPP TS 23.272. When MME receives Extended Service Request in Step 9, it detects this message is the response to the priority CS Fallback procedure initiated in step6, and the MME processes this message with priority.
6. MME sends UE Context Modification Request with CS Fallback Indicator and Priority Indication to E-UTRAN. CS Fallback Indicator indicates to the E UTRAN to move the UE to 1xRTT. E-UTRAN responds with UE Context Modification Response.
7. E-UTRAN may optionally solicit a 1xRTT measurement report from the UE to determine the target 1xRTT cell to which the CS Fallback will be performed.
8. E-UTRAN sends a HandoverFromE-UTRAPreparation Request message to the UE to start the enhanced 1xCS fallback procedure. It includes 3G1x Overhead Parameters and RAND value.
9. The MS/UE sends a Page Response message to the 1xCS IWS via GCSNA through E-UTRAN.
10. eNodeB sends to MME which in turn sends it to 1x CS IWS
11. IWS constructs the Paging Response message, and places it in the Complete Layer 3 Information message, sends the message to the MSC
12. MSC validates user and sends a Handoff Request message to the target BS with the MS Information Record IE and the IS-95 Channel Identity IE or the IS-2000 Channel Identity IE present, based on the corresponding MS Information Record IE and IS-2000 or IS-95 Channel Identity IE were present in message sent by IWS.

13. Upon receipt of the Handoff Request message from the MSC, the target BSC allocates appropriate radio resources as specified in the message. As the Handoff Request message can contain multiple cell(s) specified, the target BS can also choose to set up multiple cell(s) for the handoff request. The target BS sends null forward traffic channel frames to the MS/UE. The target BS sends a Handoff Request Acknowledge message to the MSC. The first cell in the cell identifier list IE of the message is treated as the new designated cell by the MSC. The change of designated cell occurs upon receipt of the Handoff Complete message. If the service option received in the Handoff Request message is not available at the target BS and the target BS selected a different service option for the handoff then the target BS shall include the service option it selected in the service configuration records.
14. The MSC sends a Handoff Command message to the 1x CS IWS. The MSC shall include in the Handoff Command message the service configuration records it received in the Handoff Request Acknowledge message.
15. The 1x CS IWS sends a handoff direction message to the MS/UE via the E-UTRAN using GCSNA, to instruct the MS/UE to handoff to the 1x system.
16. The E UTRAN sends Mobility from EUTRA Command to the UE with indication that this is for enhanced 1x CS Fallback operation, 1xRTT related information, and optionally the HRPD redirection information. The 1xRTT information contains 1xRTT messages related to 1x channel assignment and cause the UE to tune to and acquire this 1x channel. This is perceived by the UE as a Handover Command message to 1xRTT.
17. The E-UTRAN sends DL information transfer message, with the embedded 1x message indicating 1xRTT preparation success to the UE.
18. Since PS handover procedure is not performed then E-UTRAN sends an S1 UE Context Release Request (Cause) message to the MME. Cause indicates that the S1 UE Context Release was caused by CS fallback to 1xRTT. The S1-U bearers are released and the MME starts the preservation and suspension of non-GBR bearers and the deactivation of GBR bearers towards S-GW and P-GW(s). The MME sets the UE context to suspended status.
19. UE tunes to the 1xRTT radio access network and performs 1xchannel acquisition with the 1xRTT CS access (e.g. 1xRTT BSS). A UE supporting enhanced 1xCSFB to 1xRTT for dual receiver/transmitter configuration continues to receive/transmit data on E-UTRAN.
20. UE sends Handoff completion message to BSC.

21. The target BS sends the Alert with Information Message to the MS/UE to cause ringing at the MS. Any cdma2000 Information Records in the MS Information Record IE from the Handoff Request message, such as CPI and signal, are included in the Alert with Information Message.

22. MSC sends CPG with BCI Status ringing to MSC-O

23. When the call is answered at the MS/UE, a Connect Order is transmitted to the target BS.

24. The target BS sends a Connect message to the MSC to indicate that the call has been answered at the MS/UE.

25. MSC sends ANM message to MSC-O which indicates priority call setup is complete.

The call flow explains how each call processing nodes identify its priority call and enable end to end high probability of call completion.

5.2.2.1 Impacted Functions in System

The MME receives a S102 message which includes 1xRTT CS Paging with priority indication. In a congestion situation the MME shall use this priority indication to process this message and also the subsequent CS fallback procedure preferentially compared to other normal transactions. For this purpose and for each paging attempt memorizes that the UE is paged with priority. The MME forwards the paging message with priority indication to the eNodeB.
Table 8 shows Pagingpriority parameter defined as per 3GPP Standards

Table 8. PagingPriority (TS 36.413, 2014:143).

IE/Group Name	Presence	Range	IE type and reference	Semantics description
Paging Priority	M	ENUMERATED	(PrioLevel1, PrioLevel2, PrioLevel3, PrioLevel4, PrioLevel5, PrioLevel6, PrioLevel7, PrioLevel8, …)	Lower value code point indicates higher priority

As shown in Table *8* IE type and reference values indicate WPS priority levels.

In a congestion situation the eNodeB should handle received paging messages with priority indication with preference over normal paging messages. The Serving MSC builds priority information in page message and sends it to IWS. Other WPS specific functionalities like handling ISUP IAM with WPS specific parameters, sending ACM, CPG with WPS specific parameters are available on 3G system which provides WPS service and these functionality can be reused.

Figure 22 shows *call priority* field in GCSNA Status parameter. GCSNA status parameter is defined as below in A.S0008-C v3.0 [39] / A.S0009-C v3.0

Figure *22* shows GCSNA Status IE definition as per standards

<table>
<tr><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th><th>Octet</th></tr>
<tr><td colspan="8">A21 Element Identifier: = [0CH]</td><td>1</td></tr>
<tr><td colspan="8">Length</td><td>2</td></tr>
<tr><td colspan="5">Reserved</td><td>Priority incl</td><td>GEC</td><td>Status incl</td><td>3</td></tr>
<tr><td colspan="8">Status</td><td>4</td></tr>
<tr><td colspan="4">Reserved</td><td colspan="4">Call Priority</td><td>5</td></tr>
</table>

Figure 22. GCSNA Call Status.

As shown in Figure 22 IWS will map the priority information to Call Priority octet. The definition and purpose of each and every octet is explained in detail

Length: This field contains the number of octets in this IE following this field as a binary number.

Status Incl: This field is set to ‘1’ if the Status field is included. Otherwise this field is set to ‘0’.

GEC: If the GCSNA PDU in this message is associated with a Global Emergency Call (GEC), this bit is set to ‘1’; otherwise, this bit is set to ‘0’. Refer to [5]. If the setting of the GLOBAL_EMERGENCY_CALL value in the 1x PDU (ref. [5]) carried in the GCSNA PDU IE is in conflict with the setting of the GEC field, the GLOBAL_EMERGENCY_CALL value in the 1x PDU shall take precedence.

Priority Incl: This field is set to ‘1’ if the Call Priority field is included. Otherwise this field is set to ‘0’. In this version of this standard, the IWS shall not set this field to ‘1’.

Status: If the Status Incl flag is set to ‘1’, this field is included and coded as follows. Otherwise, if the Status Incl flag is set to ‘0’ the octet containing this field is omitted.

Figure 23 shows Status Octet defined values as per standards

Value	Status
01H	Handoff successful
02H	Handoff failure
All other values are reserved	

Figure 23 GCSNA Status IE Status Octet definition

As shown in Figure 23 only 2 values are defined and remaining values are reserved. IWS and MME will encode and decode appropriately.

Call Priority: In the direction from the A21 end point for another technology to the 1x IWS, if the Priority Incl field is set to ‘1’ then this field represents the highest priority assigned to any bearer. This field is coded with ‘0000’ representing the highest priority, and ‘1111’ representing the lowest priority. If the Priority Incl flag is set 2 to ‘0’, the octet containing this field is omitted

1x IWS to MME direction indicates the priority of the call

5.2.3 Priority Call Progression

Call progression is the functionality provided by interconnecting PSTN nodes. Interconnecting nodes mainly use SS7 signaling in circuit and Session Initiation Protocol (SIP) for packet networks. From CSFB perspective there are no changes required as CSFB its LTE Access connected to 3G network. So only access component are different. Hence once call is setup on MSC progression capabilities are all existing in MSC and can be reused. The WPS CSFB call flow is shown for completeness.

Figure 24 illustrates Successful CSFB NS/EP progression involving LEC, IXC and then call routed to MSC.

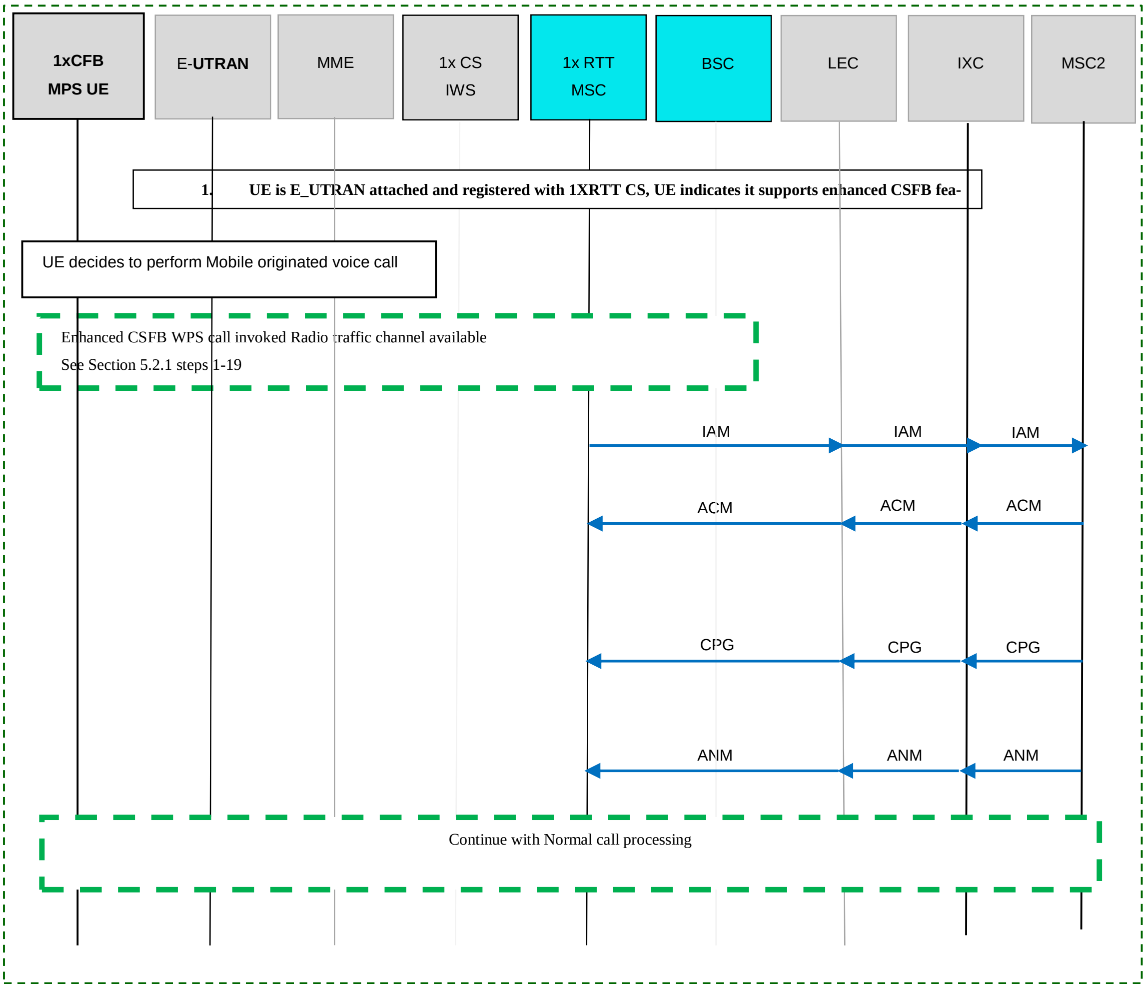

Figure 24. CSFB NS/EP call Progression – Successful call setup.

As shown in Figure 24 once access is setup message exchanged on MSC and PSTN side are same as Figure 12.

5.2.4 Priority Radio Resource Queuing

As per WPS FOC when priority user originating priority call on MSC or priority call terminates on MSC, detects "no radio resource available" condition the call needs to be queued based on priority on cell in which call originated or UE responded.

Figure 25 illustrates call flow for CSFB WPS call.

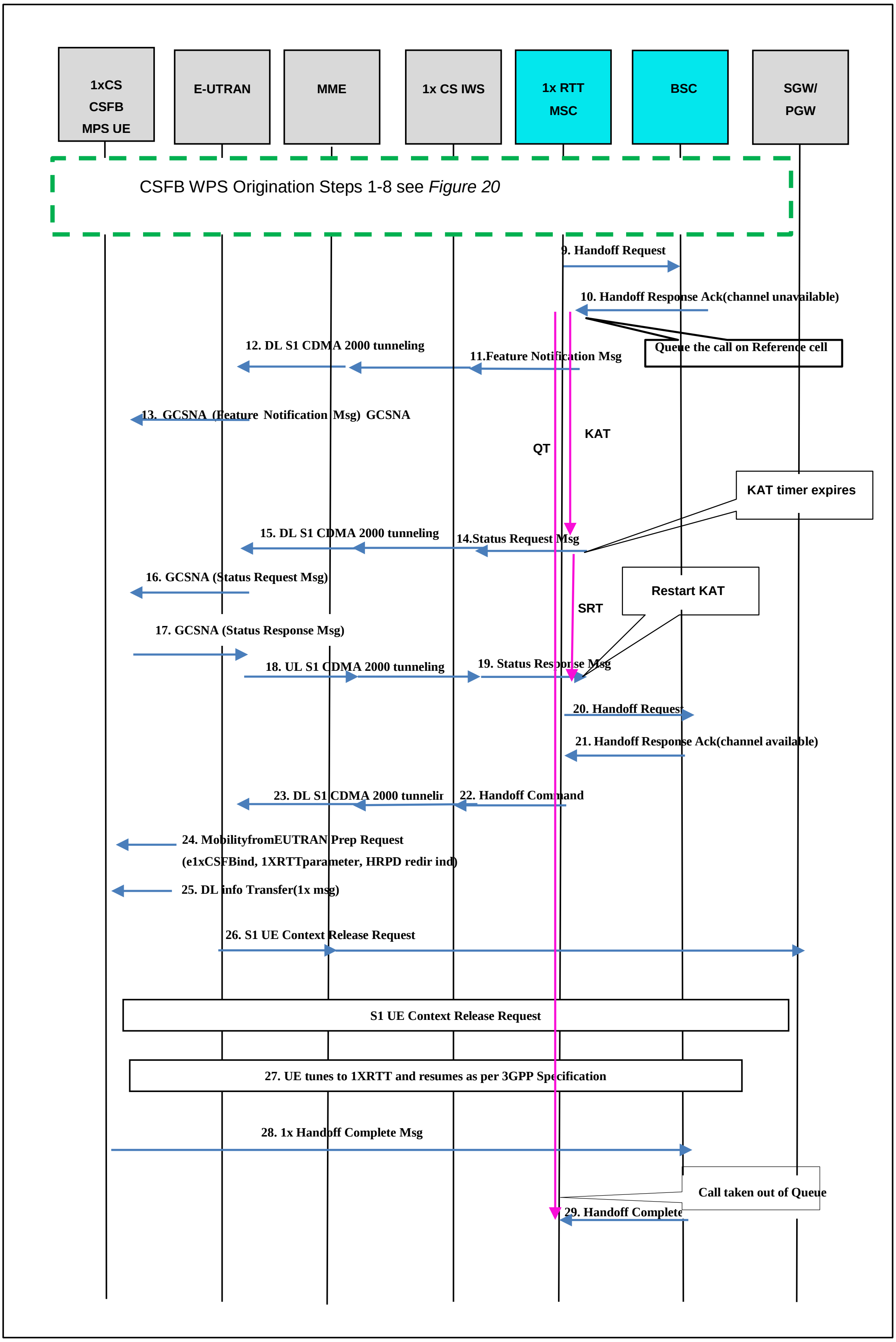

Figure 25. Successful CSFB WPS Origination – With Queuing for Radio Traffic Channel.

Steps 1 to 9 please refer Section 5.2.1

10. BSC set up channel on target cell list sent by the MSC. If channel is unavailable in all Target cell list Handoff Response with indication no channel available.
11. 1xRTT MSC upon receiving failure from BSC identifies its WPS call and queues call on Reference cell based on WPS queue entry, priority and starts QT timer. MSC then sends a Feature Notification Message to the 1xIWS confirming that the WPS call request has been queued. The Feature Notification Message includes the field RELEASE set to 0, the information record DISPLAY set to “Queued” and the information record SIGNAL with the signal type set to 00 (Tone) and the signal code set to 001010 (Pip tone on).
12. 1xIWS builds A21 message encapsulating 1x Air interface message and sends to MME
13. GCSNA message encapsulated feature Notification message is sent to UE
14. If timer KAT expires before radio resources become available, the MSC sends a Status Request Message to the UE via tunnel. The MSC starts a timer, here in referred to as the Status Request Timer (SRT), while waiting for a Status Response Message.
15. 1xIWS encapsulates this message in A21 message and sends it over S102 link to MME. MME sends to eNodeB
16. GCSNA message is sent to UE. On receipt of the Status Request Message, the MS cancels timer T42m and starts an access attempt by sending a Status Response Message on the tunnel.
17. UE sends GCSNA Status response message to eNodeB
18. MME sends A21 1x message to 1xIWS
19. IWS strips A21 header and sends CDMA2000 Status Response message to MSC. On receipt of the Status Response Message MSC cancels the SRT timer and sends a Base Station Acknowledgment Order as GCSNA L2 ack to the MS. The MS again starts timer T42m. The MSC starts timer KAT.

NOTE: The BS/MSC transmits a Base Station Acknowledgment Order to the MS to acknowledge the receipt of the Status Response Message if no message directed to the MS (e.g., Channel Assignment Message) is available within ACC_TMO x 80 ms after the receipt of the Status Response Message.

NOTE: Steps 14 through 19 could be repeated several times.

20. Upon queue retry, MSC identifies this call needs to be served and initiates resource allocation process. Request RNC to allocate resources
21. Steps 21-29 please refer section 5.2.1 11-19 steps
29. Once MSC receives Handoff completion cancels all timer and removes CSFB call call from queue and progress with call setup.

WPS CSFB origination with successful queuing and resource availability scenario is shown. There are possibilities like queue timeout, queue full and other scenarios which is not discussed in this study.

Figure illustrates sequence of events during termination.

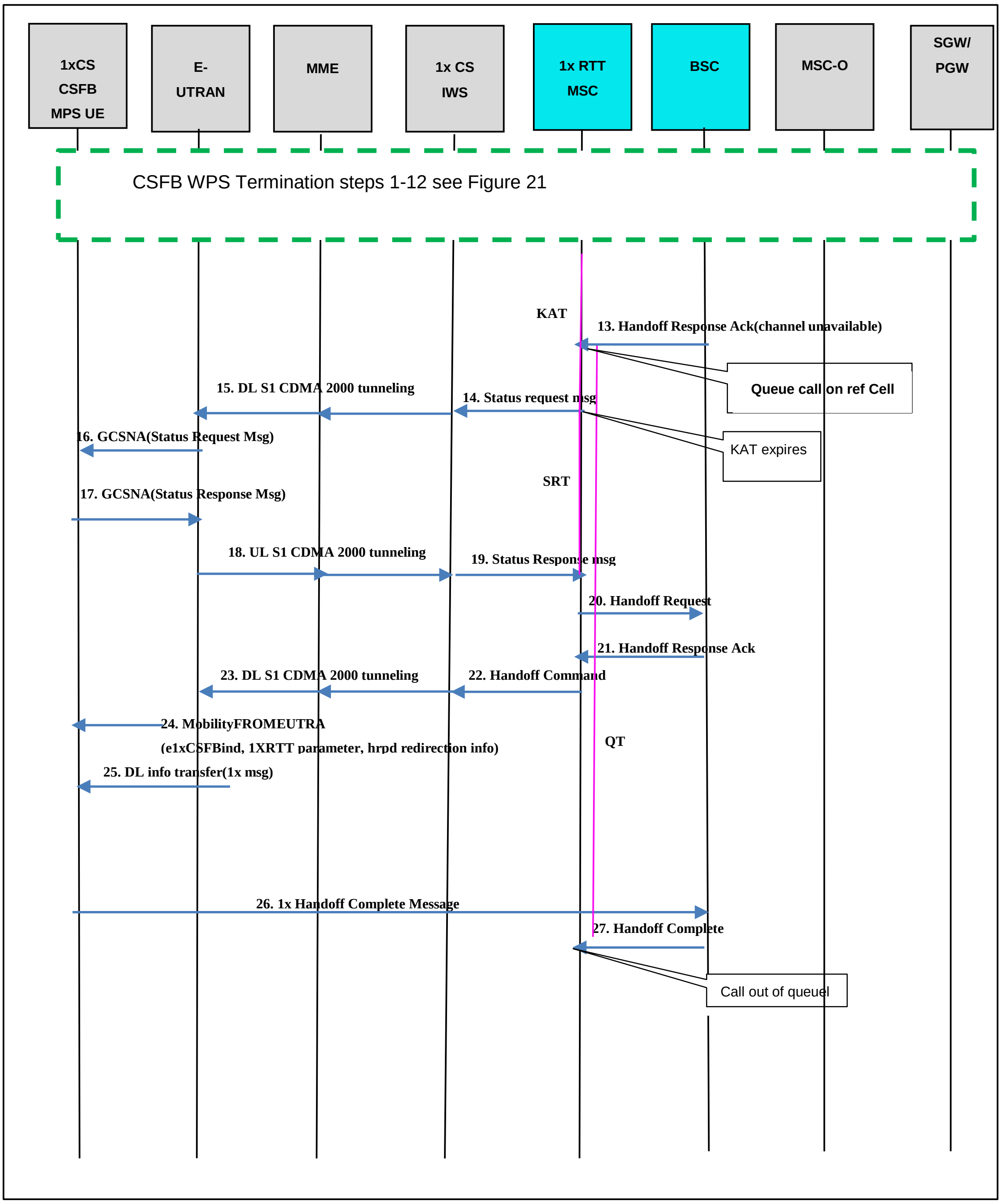

Figure 26 Successful CSFB NS/EP Call Termination – With Queuing for Radio Traffic Channel.

CSFB NS/EP Termination call flow as shown in Figure 26 explains sequence of events for queuing on MSC and how call is setup. Detailed steps is explained as a numbered list.

Steps 1-12 refer Figure 21

Step 13 refer step 10 of Figure 25

Step 14 -27 refer step 14-29 of *Figure 25*

CSFB NS/EP termination with successful queuing and resource availability scenario is shown. There are possibilities like queue timeout, queue full and other scenarios which is not discussed in this study.

5.2.4.1 Impacted Functions in System

MSC upon encountering “no radio resource available” condition shall queue call based on HPURDA algorithm. MSC stores all information received from IWS in per call data block so it can use the same info to send Handoff request to target BSC. Upon keep alive timer expiry MSC send Status Request message to 1x CS IWS. MSC shall handle Status Response message from 1x CS IWS. MSC shall support sending feature notification message. Once resource is allocate call is taken out of queue.

1x CS IWS shall handle Status Request message from MSC and tunnel it as GCSNA message over S102 tunnel. Also handle Status Response/Extended Status response from UE. IWS shall handle Feature notification message and tunnel it as GCSNA message over tunnel.

Table *9* illustrates the GCSNAOption that is used for identifying circuit switched services provided over the GCSNA tunnel and the set of 1x messages for providing the services.

Table 9. GCSNAClass Definitions (3GPP2 C.R1001)

GCSNA Class	GCSNA Class Revision	1x Service	Note
0	0	Release 8 1xCSFB from E-UTRAN	
	1	Release 9 e1xCSFB from E-UTRAN	
	2	C.S0097-A supported eCSFB	
1	0	SRVCC from E-UTRAN	
2 -31	NA	Reserved	

As shown in Table *9*. GCSNAClass Definitions the GCSNAOption is divided into two fields, GCSNAClass and GCSNAClassRevision. GCSNAClass identifies circuit switched services to be provided by certain interworking scenarios. GCSNAClassRevsion identifies actual messages supported over the tunnel. The messages actually used in the implementation may be a subset of those allowed by a specific GCSNAOption.

Table 10 describe GCSNAClassRevision and 1x message supported as per 3GPP2 standards

Table 10. 1x Messages List for GCSNAClass 0 and 1 *(*3GPP2 C.R1001)

GCSNA Class 0 Revision	GCSNA Class 1 Revision	Direction	1x message	Note
2	N/A	Forward	Status Request Message	
2	N/A	Forward	FeatureNotification Message	
2	N/A	Reverse	Status Response Message Extended Status Response Message	

As shown in Table 10 GCSNAClassRevision supports Status Request, Status Response and Feature Notification message in the tunnel in addition to call setup messages and this will enables queuing functionality for WPS CSFB.

Design Issues on MSC

In case of 3G serving cell is the cell in which the mobile originates or responds to page and cell remains the same till the call is setup. So for WPS calls when *no resource available* condition is encountered call is queued on serving cell on MSC. Call is retried for resources on same cell. In case of CSFB eNodeB send reference cell and target cell list and Target BSC allocates resources on all target cell. Targetcelllist is sorted based on the Pilot Strength measurement with highest being first cell. Reference cell is internal mapping of LTE cell to 3G cell when UE is camping on LTE and it is not necessary call will be setup on this cell. When *no resource available* condition is encountered call has to be queued and here one is in a situation on which cell to queue call. WPS FOC states next available resource to be provided to WPS call if HPURDA algorithm returns its WPS turn. Some design options are discussed.

Option 1: Queue call in Reference cell. During queue retry MSC to send Handoff request and Target BSC to allocate resources on all target cells and UE can tune to any of the cell. Once UE tunes, MSC remove call from reference cell Queue. This is kind of having entry just for queuing purpose.

Figure *27* illustrates priority queue on MSC before call is queued and after.

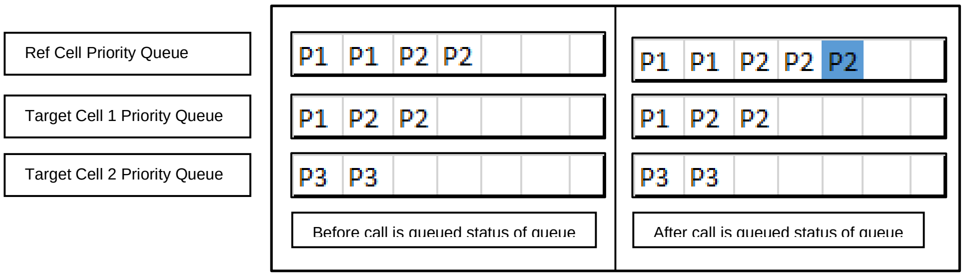

Figure 27. Queuing design with option 1.

As shown in Figure *27*CSFB call of priority P2 is queued in reference cell when there is no radio resource.

Pro: Easy to implement

Con: There is possibility high priority call in Target Cell 1 queue waiting for resource but radio resources are provided to call which is Reference cell queue and is also of lower priority. Not satisfying WPS compliance high priority calls need to be served first.

Option 2: Make queue entry in all targetcelllist and when retry message is sent just mark in other cells so retry message is not sent from other cells. Once UE tunes to any of target cell remove queue entry. This way it guarantees high priority call is typically served first.

Figure 28 illustrates queuing of CSFB WPS call with design option 2.

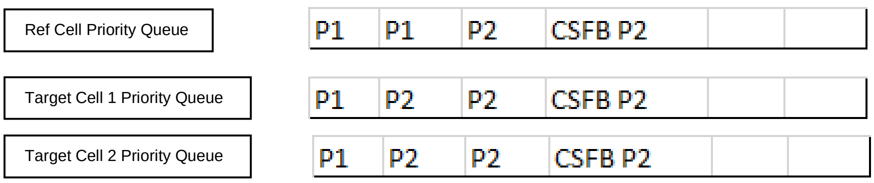

Figure 28. Queuing design with option 2.

As shown in Figure *28* when resource not available condition occurs call is queued on all the cell/sector priority queue.

Pros: Compliance to WPS requirement

Con: Complicated design as we need to add entry to all queue and remove them.

5.2.5 Priority Call Trunk Queuing

When CSFB user originates a WPS call and there are no trunk resources on originating MSC call is queued for trunk resources. Call is queued on Trunk group and uses FIFO queue. Queue timer is started which ensures that the call remains in the queue for a specified period of time. Trunk queuing is provided only for SS7 and MF trunks. This can be a circuit or packet trunk. Once a trunk member becomes available the call is notified so the WPS call can progress passing HPC parameters to subsequent nodes which can provide priority on the other nodes. Trunk queuing and propagation of parameters remains the same as in 3G. There are no changes from the CSFB perspective.

Figure 29 illustrates Trunk Queuing at Originating MSC and Terminating IXC and Successful Call Setup

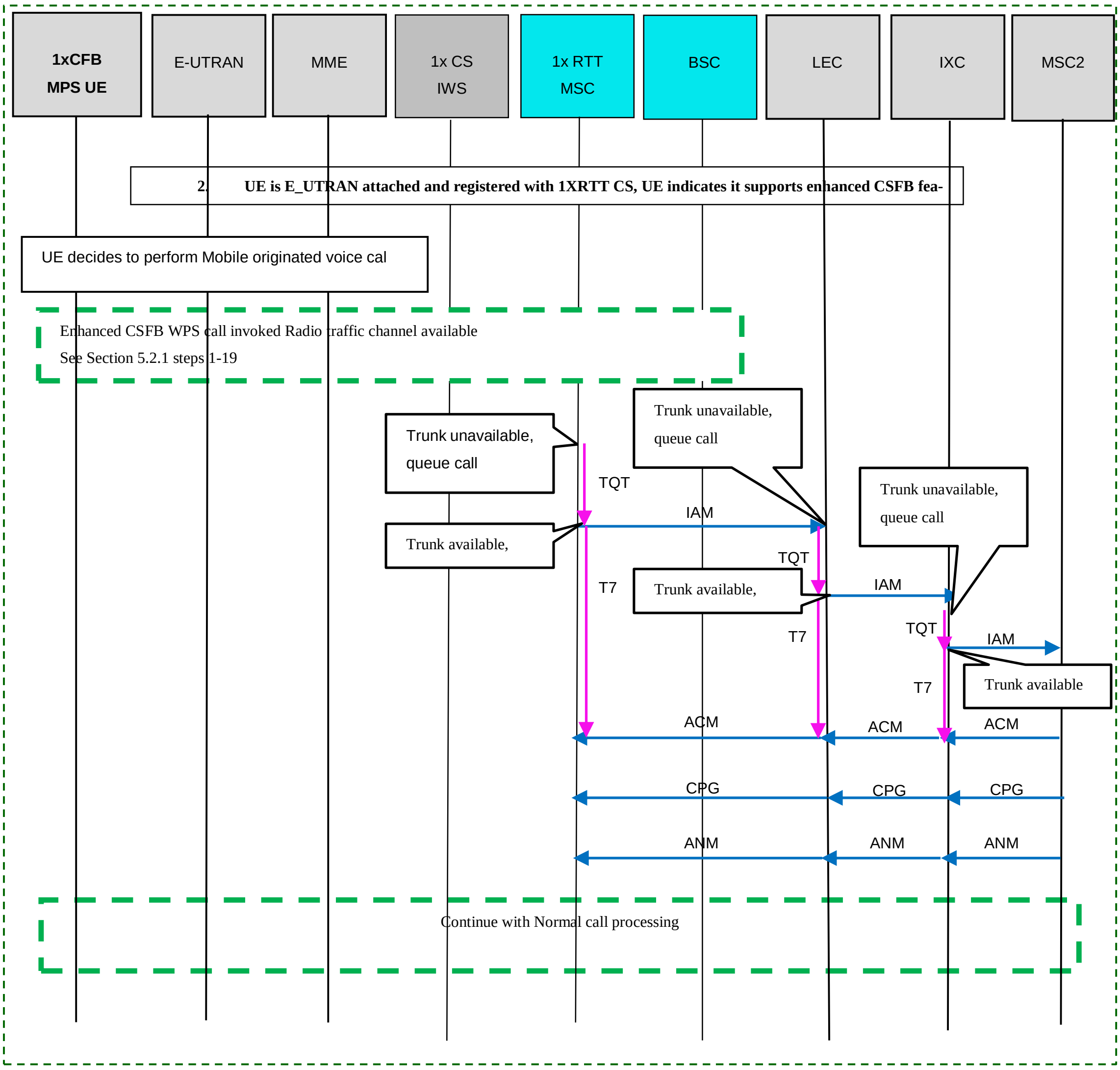

Figure 29. Trunk Queuing at Originating MSC and Terminating IXC - Successful Call Setup

As shown in Figure 29 Trunk queuing for CSFB is same as Figure 15 as changes for CSFB are on access side.

5.3 CSFB WPS Enhanced Overload Performance

As discussed in section 3.3.3 during any disaster or emergency conditions wireless networks get congested. Inspite of LTE offering high speed data, higher bandwidth congestion is unavoidable as usage is high. Networks getting congested there is high probability WPS users are also faced with access denial (refer) and overload message shedding. (). To overcome access denial issue CSFB WPS uses are provisioned with access class 11. This will enable WPS users to access system as network will block other users entry.

For CSFB IWS is entry point from other technology to 3G. Hence overload controls are incorporated at IWS to ensure WPS CSFB calls are not shed.

5.3.1 Impacted Functions in System

IWS overload design have 2 levels such as L1 and L2. IWS enters L1 overload when queue delay exceeds certain threshold. L2 overload is based on buffers. When system enters L1 overload IWS is designed to prevent shedding of CSFB WPS origination. Generally at IWS CDMA2000 message parameters are not decoded they are just parsed and sent to subsequent nodes for call processing. In order to do overload design IWS may have to open CDMA2000 origination message and check dialled digits. IWS being router opening every origination message and decoding called party number can result in queue delays and this has to be optimized. When system is in overload shedding is the way to bring the system out of overload. Allowing WPS calls based on dialled digits has its own drawback such as misuse by fraudulent users. To prevent that validation needs to be based on user subscription but this requires subscription data to be available on IWS. Network with huge subscriber has to have copy of subscriber data on IWS which result in memory issues. Thorough analysis has to be done to verify tradeoff between delaying validation and memory.

6 Discussion and Conclusions

This section presents the conclusion of the study. It contains the summary and evaluation of the study with a discussion about its validity and reliability. It also proposes further area of analysis for CSFB WPS.

6.1 Summary

The objective of this study was to propose a solution for enhanced CSFB priority call handling on LTE networks interworking with CS Domain. This study was looking for an answer to the following research question: Add the research question here

The current context of the service in 3G networks and CSFB was analysed and used as base for this study. The analysis was made to ease the understanding of the needs for changes. The next step was a literature review, which was done to collect information and knowledge about the enhanced multimedia priority services. During the review the requirement documentation produced by 3GPP was found very valuable. Therefore these 3GPP documents were used for further studies. Based on the literature review, enhanced multimedia priority service concept was presented as well as the new requirements it added for CSFB service. These requirements were then analysed together with the information about the current context of the system in CDMA 3G, to see whether they had an impact on the 3G functionality or not. After this impact analysis, modifications in the current system were proposed. The proposed modification form the solution for compliance of the wireless priority service with CSFB calls.

6.2 Evaluation

The evaluation of the outcome of the study compares the research objectives defined in the beginning of this study against its final outcomes. The objective of this study was to develop a solution to address Wireless Priority Service for enhanced CSFB calls. The outcome of this study is two folded. First, the study presents modified call flows for WPS CSFB calls and proposed solutions to handle changes. Second, it identifies issues which can arise with these new changes and some solutions to handle the same. Validity and reliability are done by analysing standards to ensure messages and parameters are supported so specified solution can be met.

6.3 Future Steps

This study only took a subset of call flows and requirements from WPS FOC and defined the same for CSFB WPS and proposed impacts to the system functions. There are additional requirements such as handling of an invalid user, release/reorder trigger, and partial dialed digits which needs to be further studied for WPS CSFB calls. The study mainly considered PSTN nodes and circuit switched based interconnect switches. Currently all nodes are packetized and hence the support of those requirements needs to be studied. MSC also interacts with IMS components and the support of resource priority header in CSFB WPS needs to be studied. Also operational measurements, which help to evaluate the total number of WPS calls made in the system, and other details needs to be thoroughly studied. WPS has a lot of interactions with other features such as the remote feature activation and this needs to be carefully studied for CSFB calls. CSFB WPS entails the sending of *Status Request Messages* to MSs in some instances. An interoperability testing will be needed to ensure an appropriate behavior of MSs that are not compliant with TIA/EIA/IS-95-A+TSB74.

One of the hurdles of this solution to be adopted by vendors and operators is that the phones must be tested and certified for proper compatibility and performance for WPS/MPS. These would have to be new phones with the LTE (data) as well as the eCSFB capability and this requires government funding. The SRVCC (Single Radio Voice Call Continuity) solution enables operators to use VoLTE and handoff to legacy systems, hence vendors and operators to implement fully compliant WPS CSFB needs a good motivation.

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